Neutrinoless Double-Beta Decay

NuFact-2015
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Rio de Janeiro, Brazil

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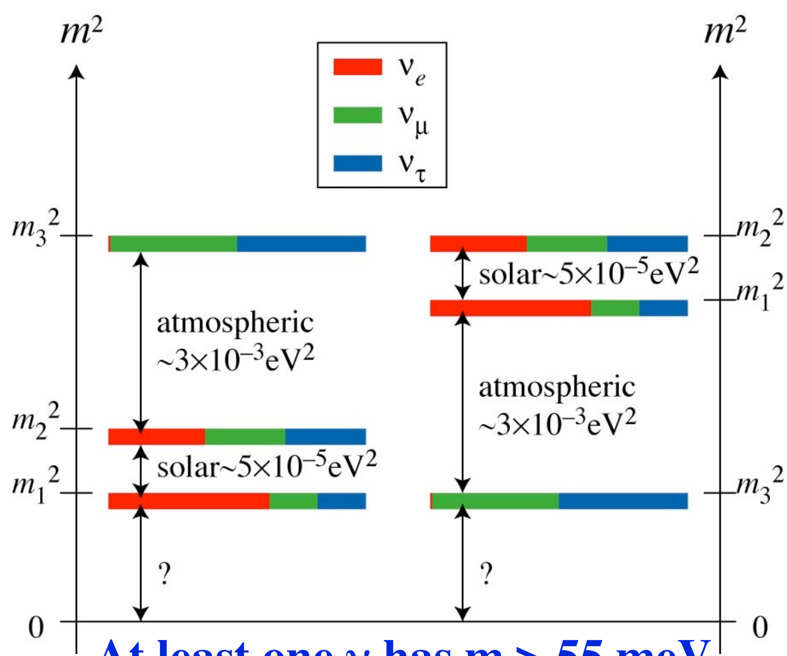
UC Berkeley/LBNL

Neutrino Physics Landscape

Neutrino mass hierarchy

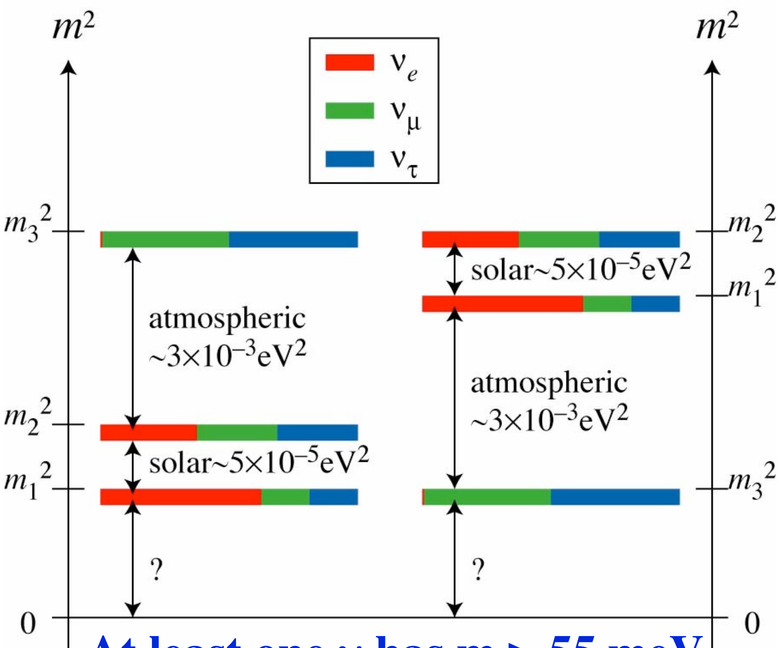


At least one ν has m > 55 meV

Neutrino Physics Landscape

- Compelling evidence for
  - Neutrino flavor-changing oscillations
  - (therefore) finite neutrino masses
  - Mixing angles are well measured

Neutrino mass hierarchy

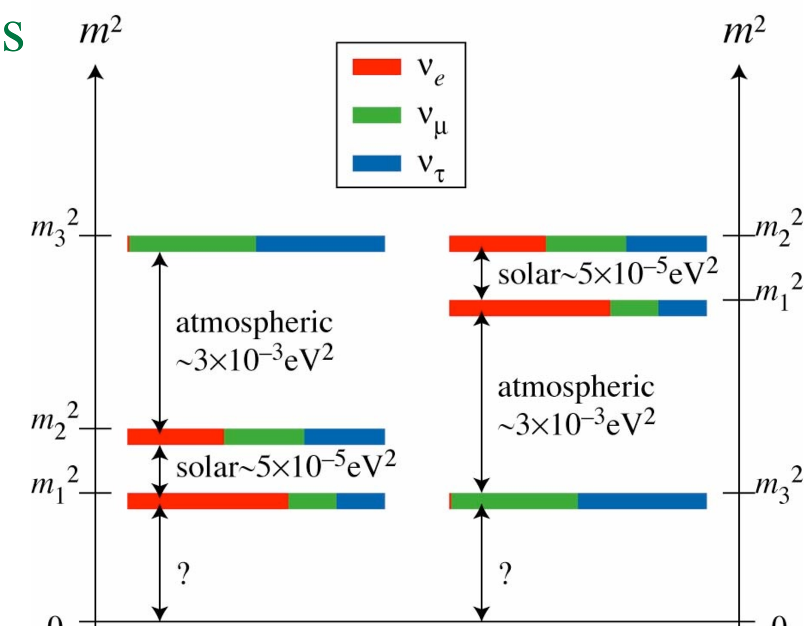


At least one ν has m > 55 meV

Neutrino Physics Landscape

- Compelling evidence for
  - Neutrino flavor-changing oscillations
  - (therefore) finite neutrino masses
  - Mixing angles are well measured
- Open questions in ν Physics:
  - How many neutrinos?
    - ☞ Sterile neutrinos ?
  - What is absolute scale of ν mass ?
  - How are masses arranged ?
  - Are neutrinos responsible for matter-antimatter asymmetry ?
  - Majorana or Dirac neutrinos ?
  - Is Lepton Number conserved ?

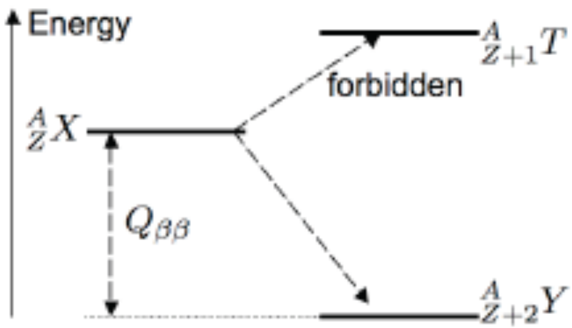
Neutrino mass hierarchy

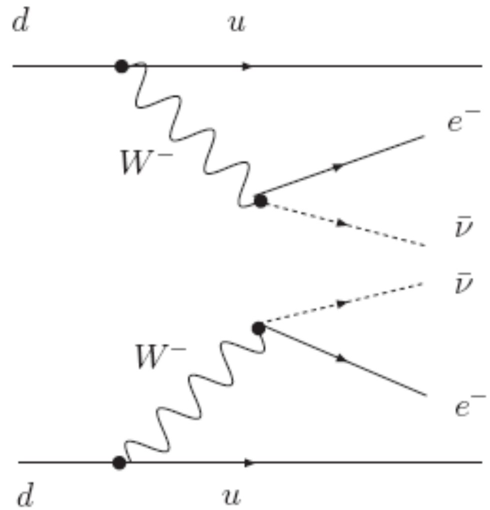


At least one ν has m > 55 meV

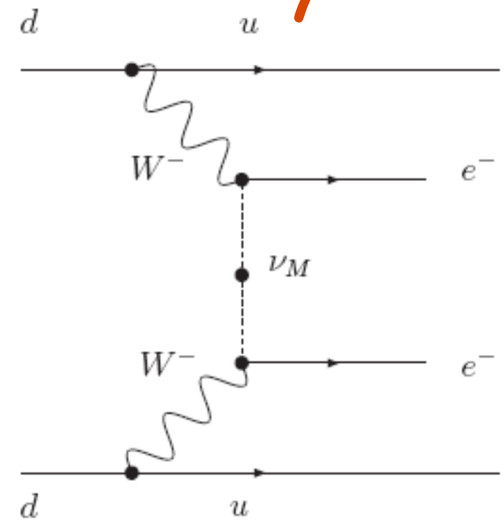
?

Neutrinoless Double-Beta Decay

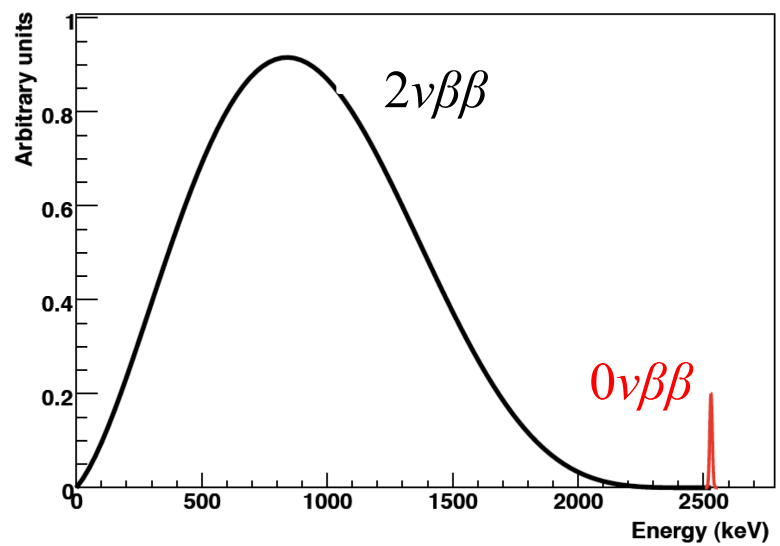




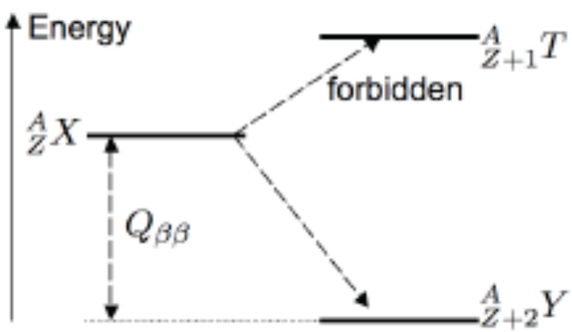
SM 2νββ decay $\tau \geq 10^{19}$ y

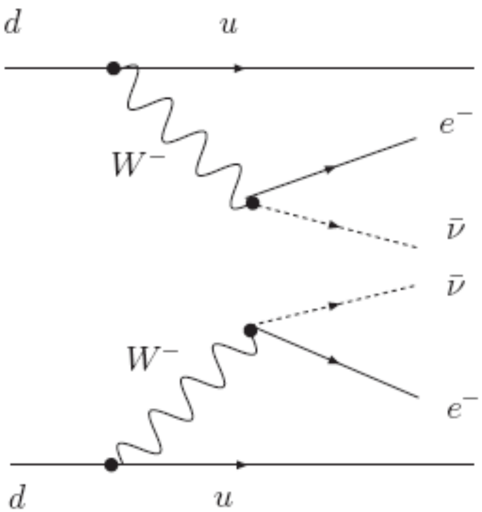


0νββ $\tau \geq 10^{25}$ y



Neutrinoless Double-Beta Decay





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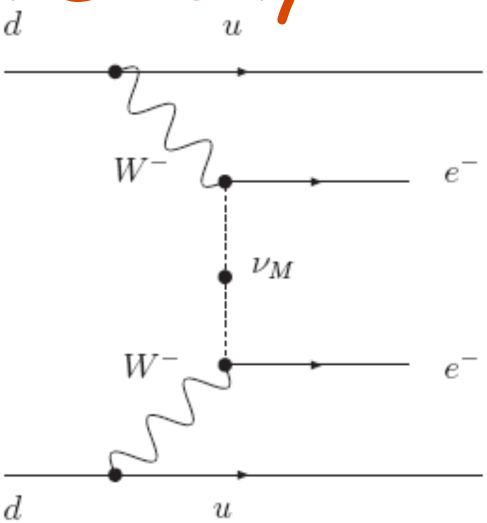
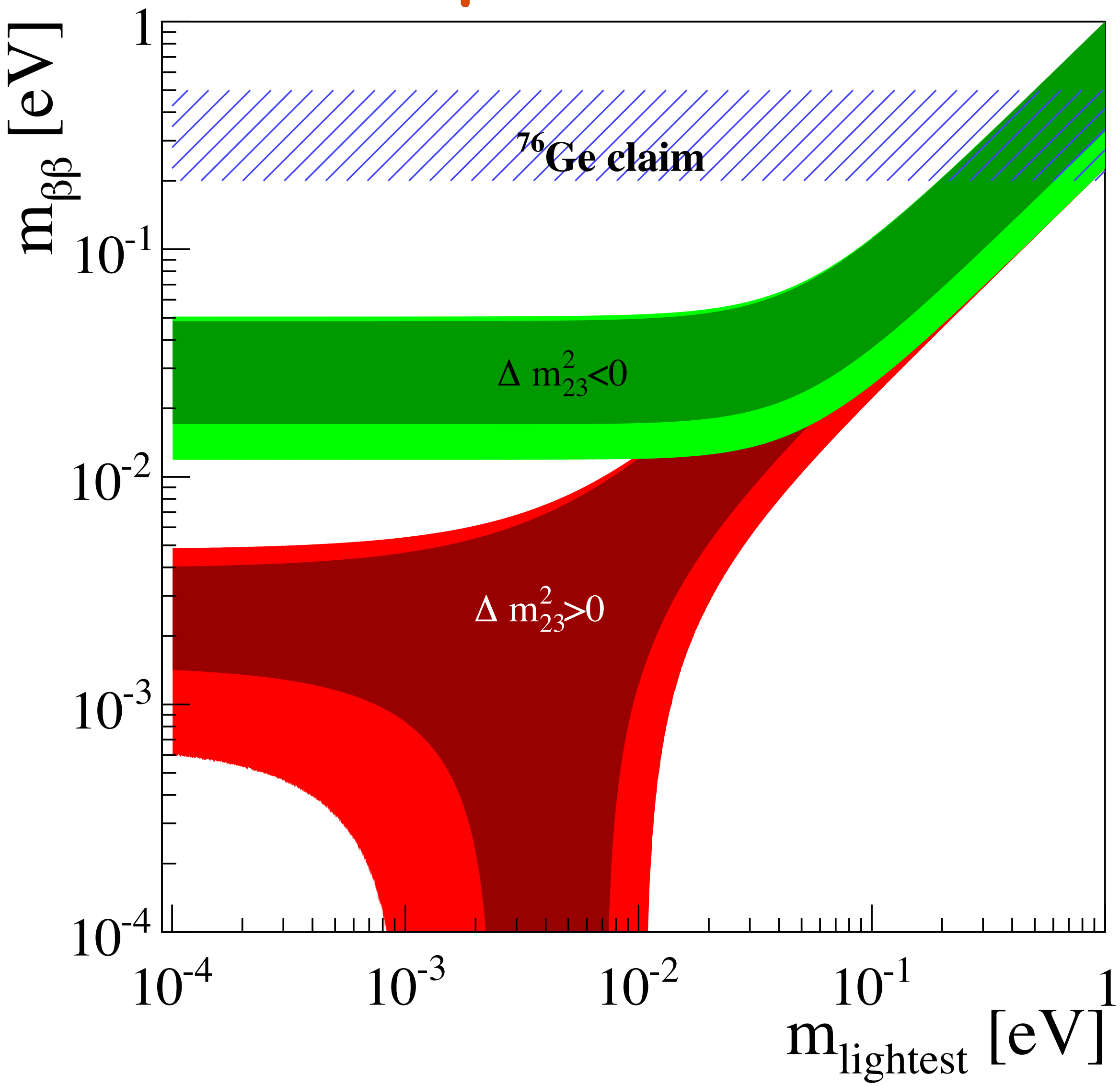


0νββ $\tau \geq 10^{25}$ y

- Observation of 0νββ would mean
  - Lepton number violation
  - Neutrinos are Majorana particles
  - Rate measures (effective) electron neutrino mass

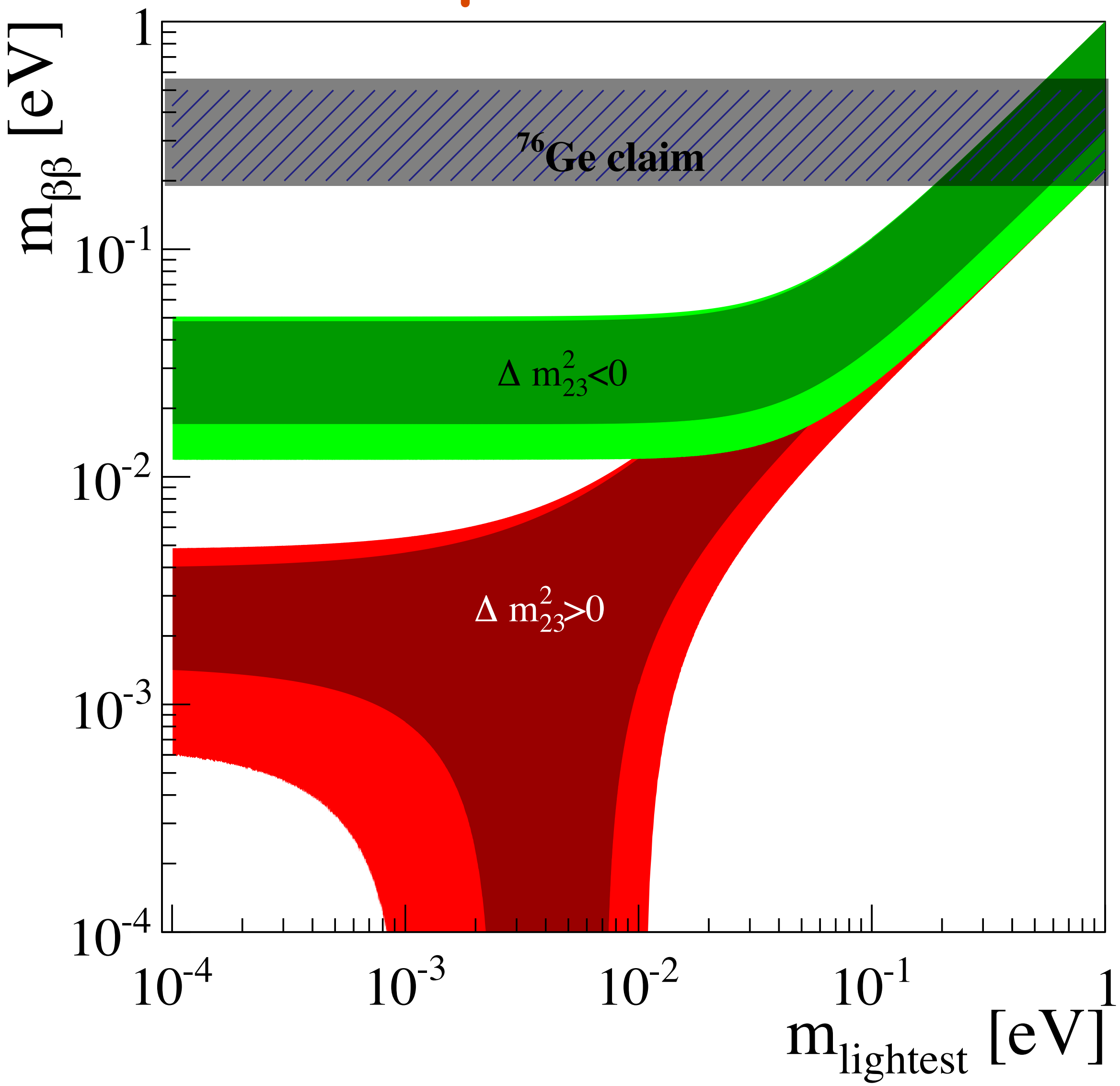
$$\boxed{m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|}$$

Experimental Sensitivity



$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

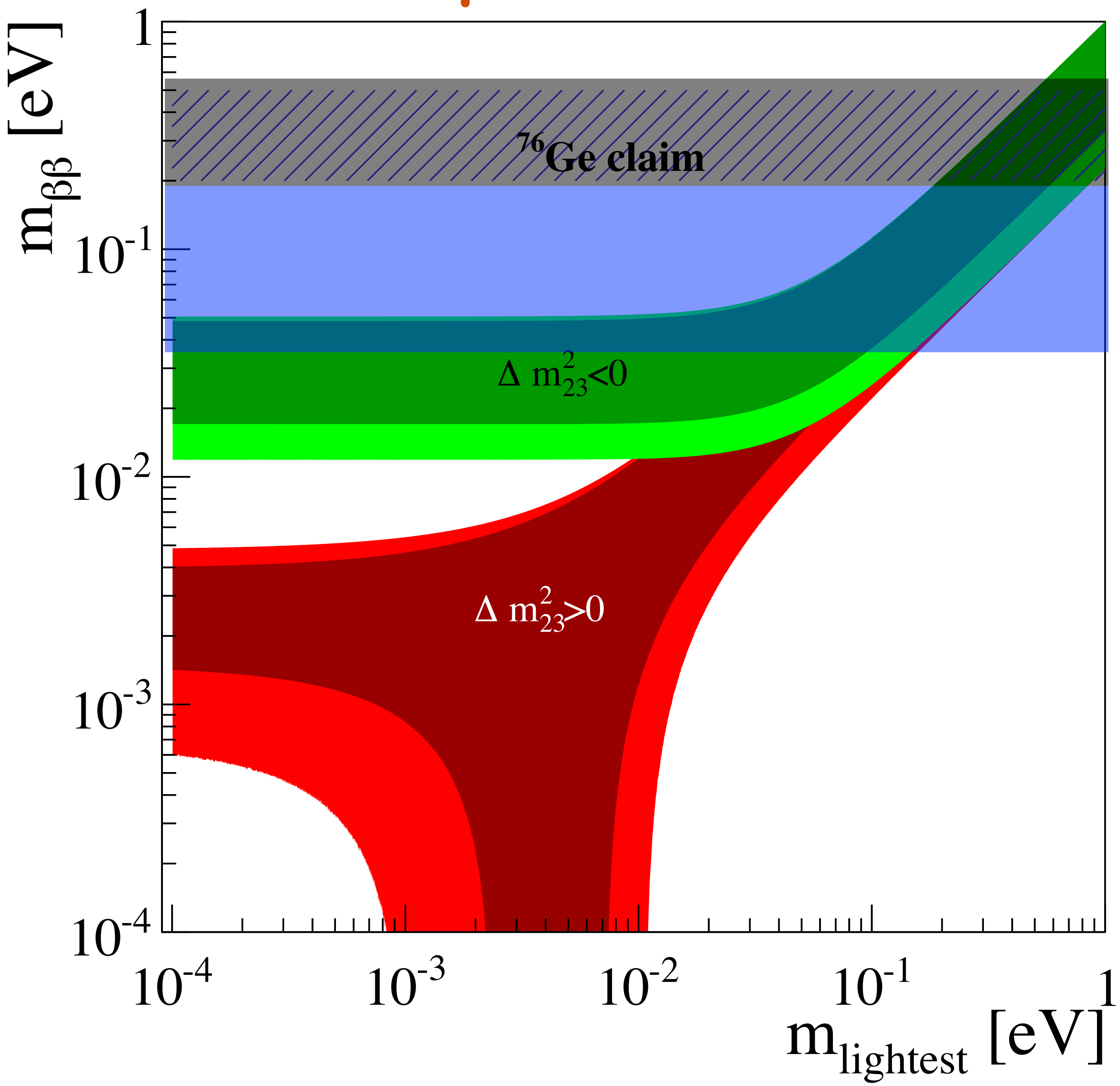
Experimental Sensitivity



Past and present (~10 kg)

$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

Experimental Sensitivity

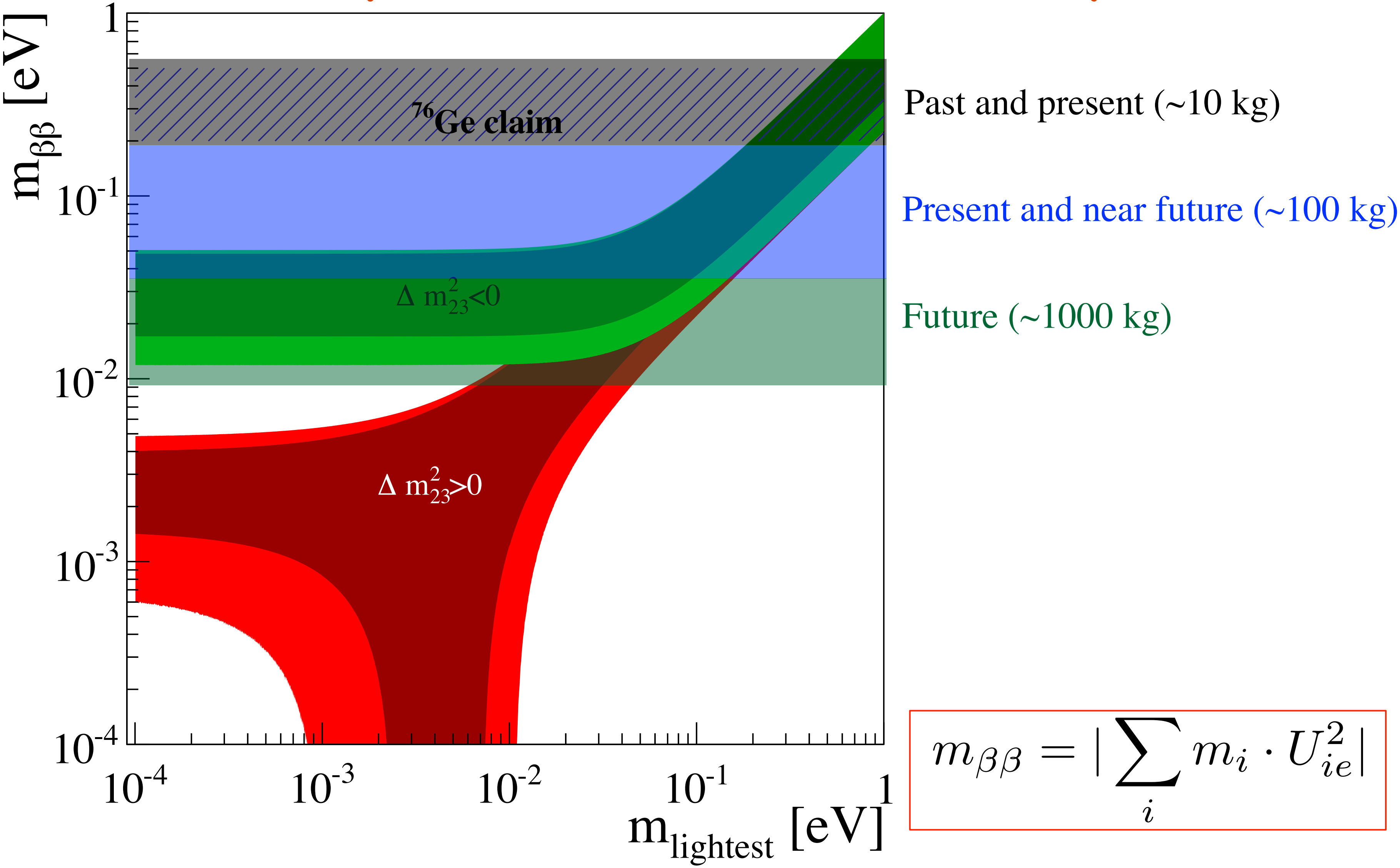


Past and present (~10 kg)

Present and near future (~100 kg)

$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

Experimental Sensitivity



$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

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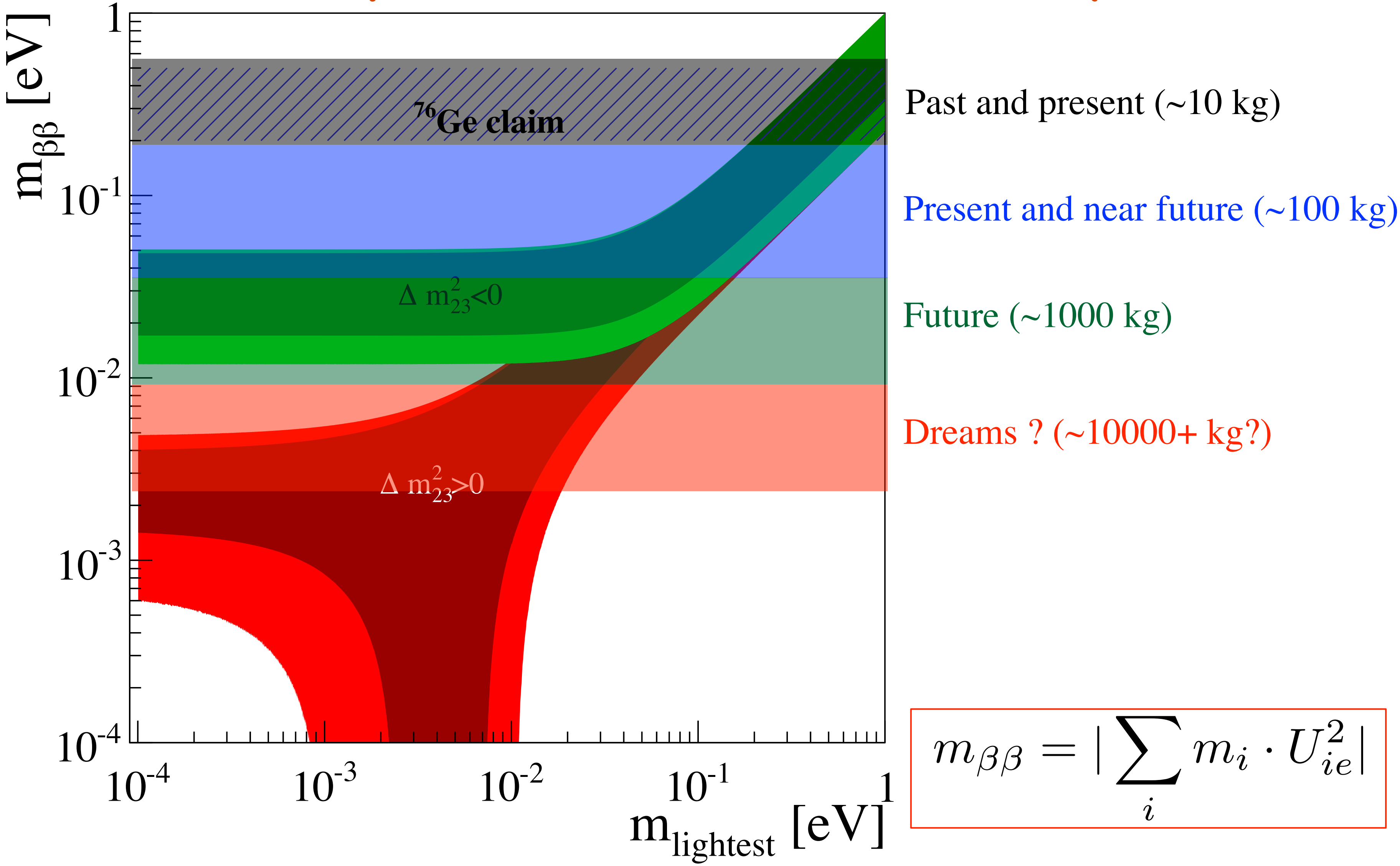


$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

0νββ Rate and Neutrino Mass

0νββ rate

Phase space $\propto Q^5$

Nuclear matrix element

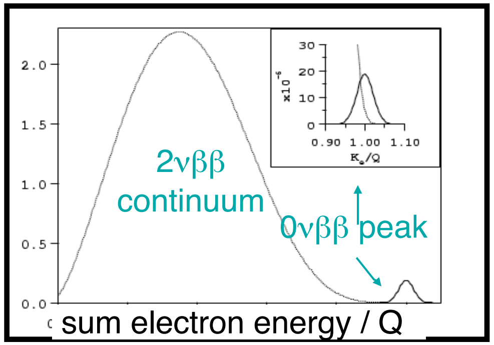
Effective neutrino mass

$$\Gamma = 1/\tau = G_F^2 \Phi(Q,Z)\, |M_{0\nu}|^2 \langle m_{\beta\beta}\rangle^2$$

high Q candidates preferred

large phase space

low background



[2039 keV (^{76}Ge) ⇔ 4271 keV (^{48}Ca)]

^{238}U γ end at 2.4 MeV

^{232}Th γ end at 2.6 MeV

$\tau^{0\nu}$~10^{24}–10^{26} years: large mass and extremely low backgrounds needed (underground labs, ultra purity materials, active rejection of backgrounds)

Experimental Sensitivity

Half-life	Expected Signal (counts/tonne-year)
5×10	~100
5×10	~10
5×10	~1
5×10	~0.1

Sensitivity scaling:

$$\left[T_{1/2}^{0\nu}\right] \propto \varepsilon\mathit{ff} \cdot I_{abundance} \cdot \sqrt{\frac{Source\ Mass \cdot Time}{Bkg \cdot \Delta E}}$$ (background-limited)

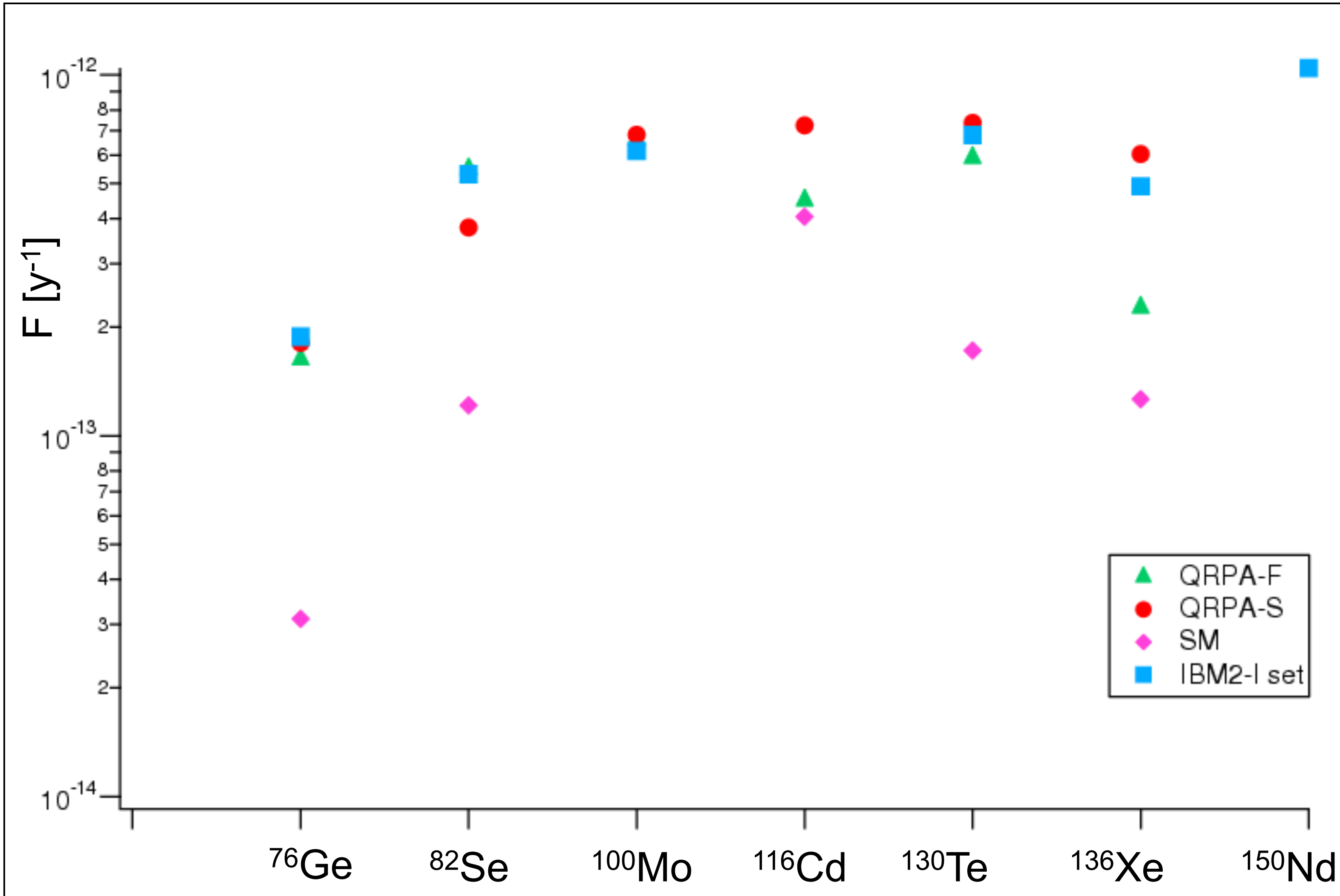
$$\left[T_{1/2}^{0\nu}\right] \propto \varepsilon\mathit{ff} \cdot I_{abundance} \cdot Source\ Mass \cdot Time$$ (background-free)

Experimental challenge:

- ✓ Increase *Mass* (200-1000 kg for current experiments): $$, R&D
- ✓ Increase *Isotopic Abundance*: $$
- ✓ Decrease *Bkg* (ultimately to 2νββ limit): radiopurity, active rejection
- ✓ Decrease *ΔE*: technology choice

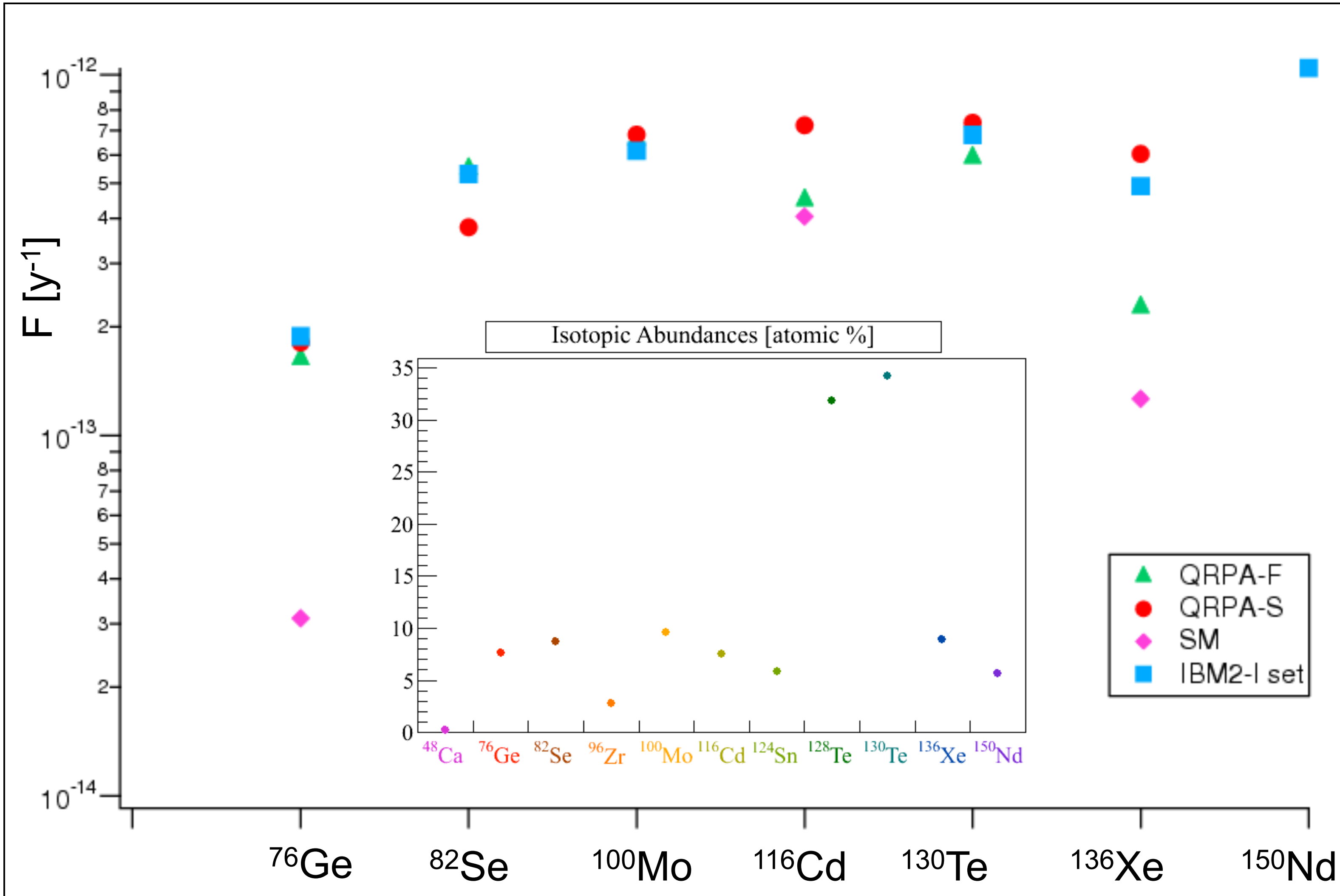
0νββ Isotopes: Figure of Merit

$F = G_F^2 \Phi(Q,Z) |M_{0\nu}|^2 m_e^2$ [y^{-1}] (Want as high as possible)

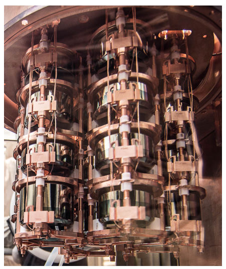


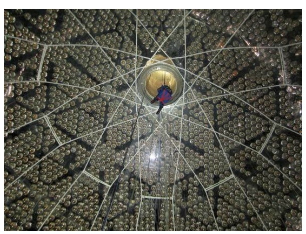
$0\nu\beta\beta$ Isotopes: Figure of Merit

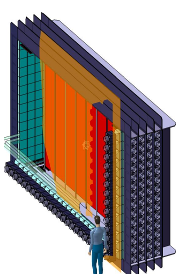
$F = G_F^2 \Phi(Q,Z) |M_{0\nu}|^2 m_e^2$ [y^{-1}] (Want as high as possible)



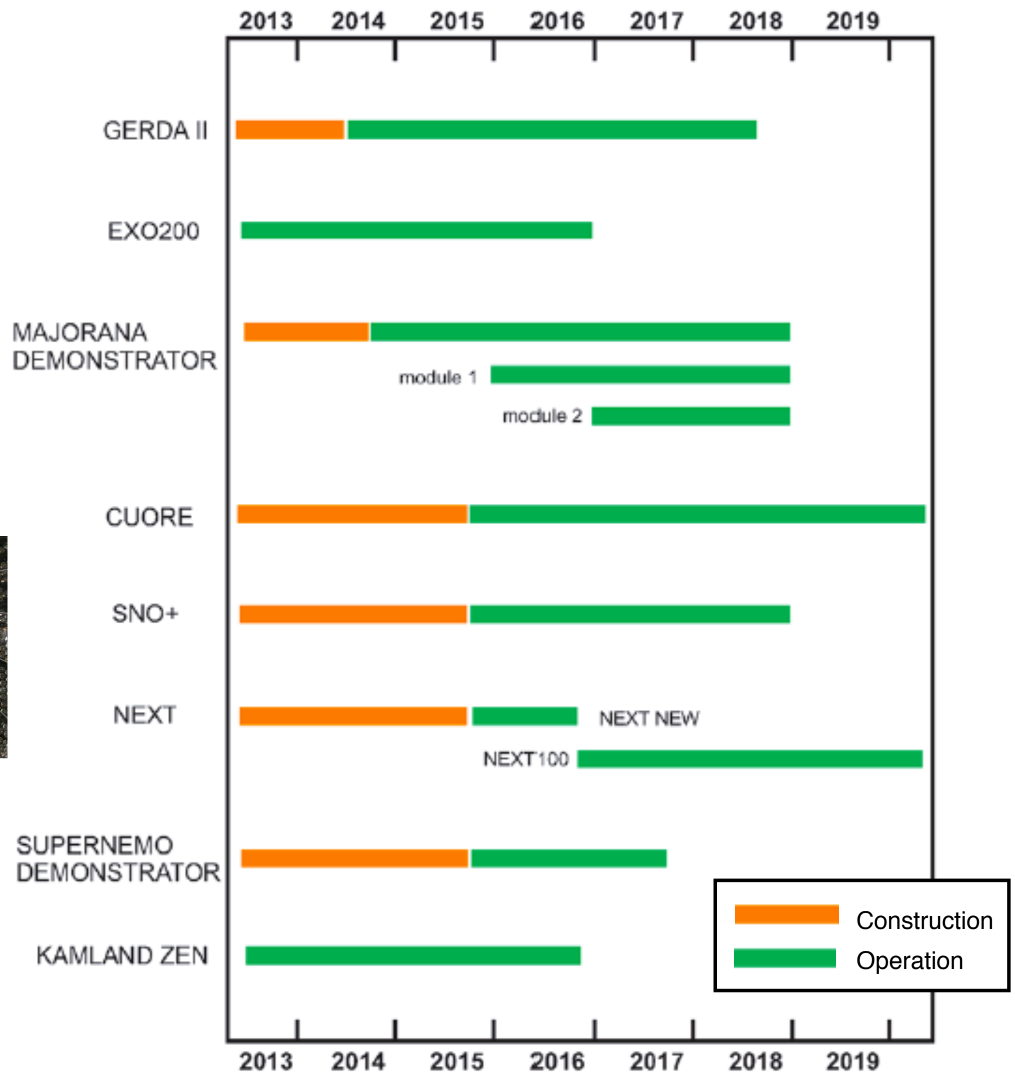
Diverse, Vibrant Program

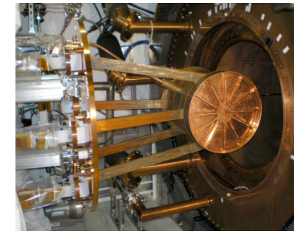


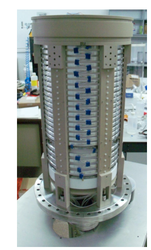




NLDBD Sub Committee Report to NSAC

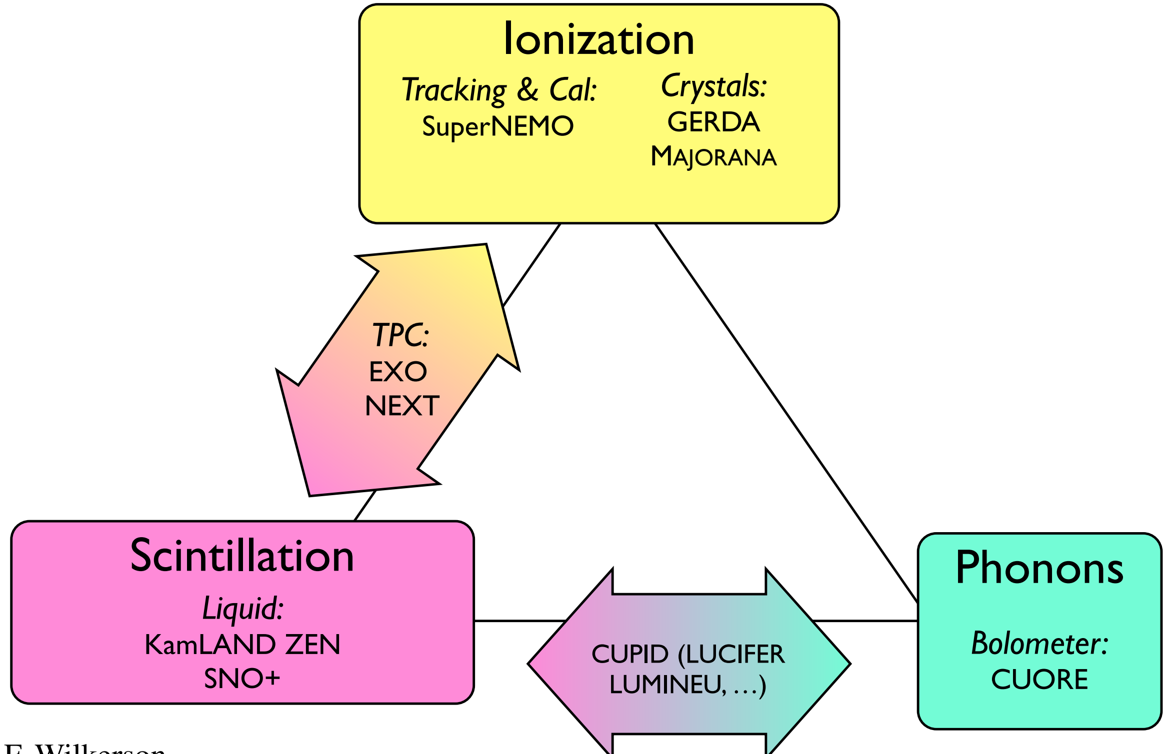






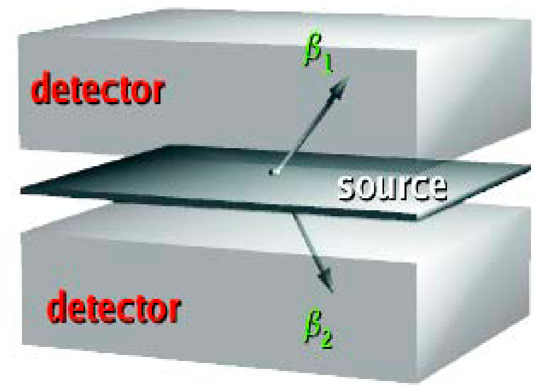
J.F. Wilkerson

Detection Techniques

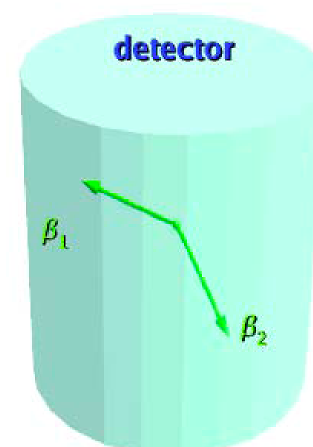


J.F. Wilkerson

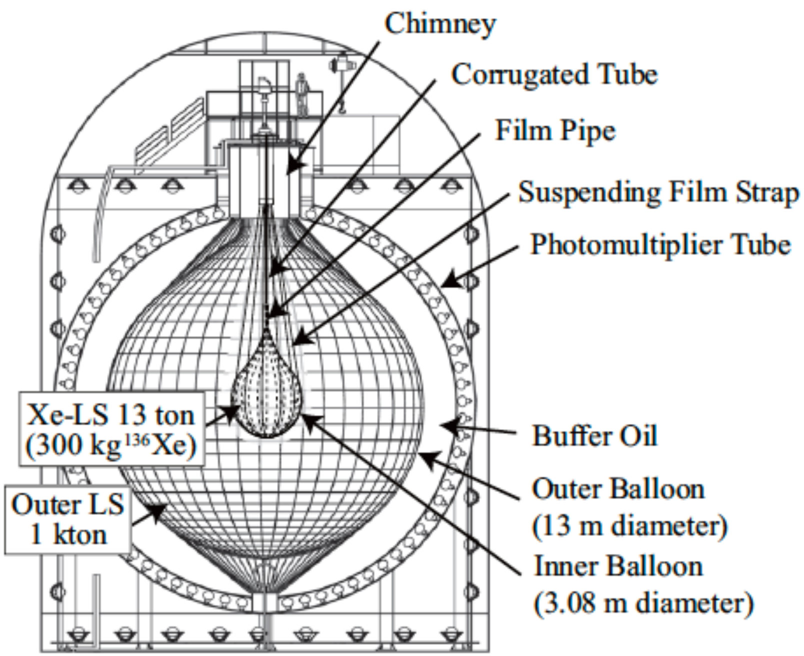
Source external to detector
(NEMO, SuperNEMO)

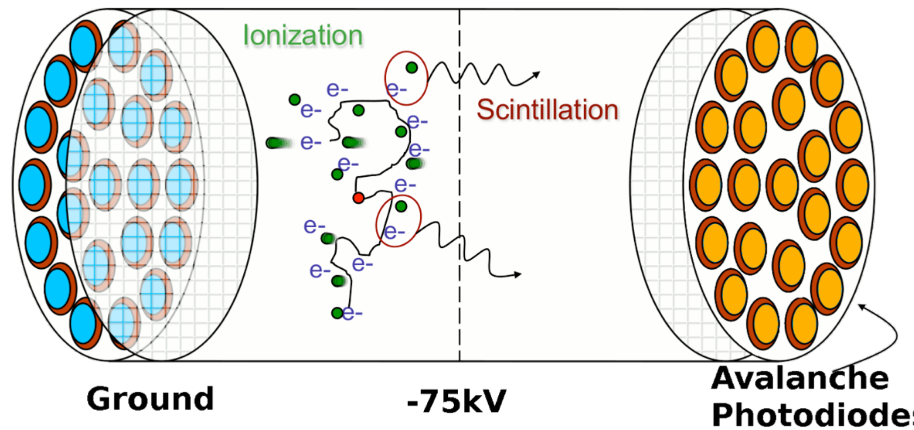


Source internal to detector
(most common)



Current State of the Art: ^{136}Xe

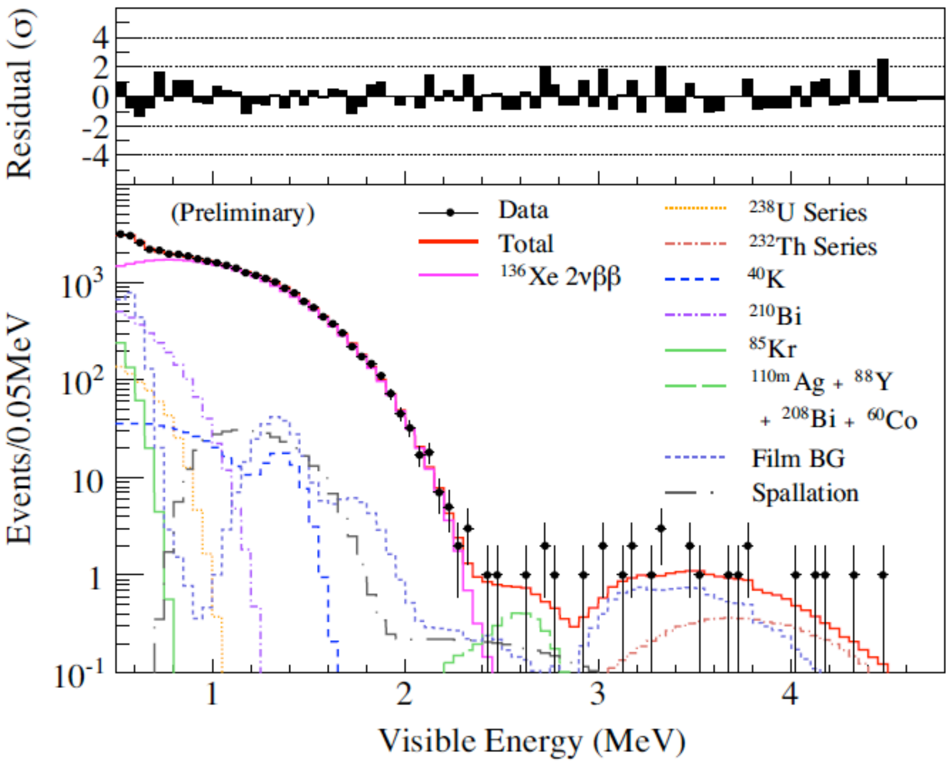


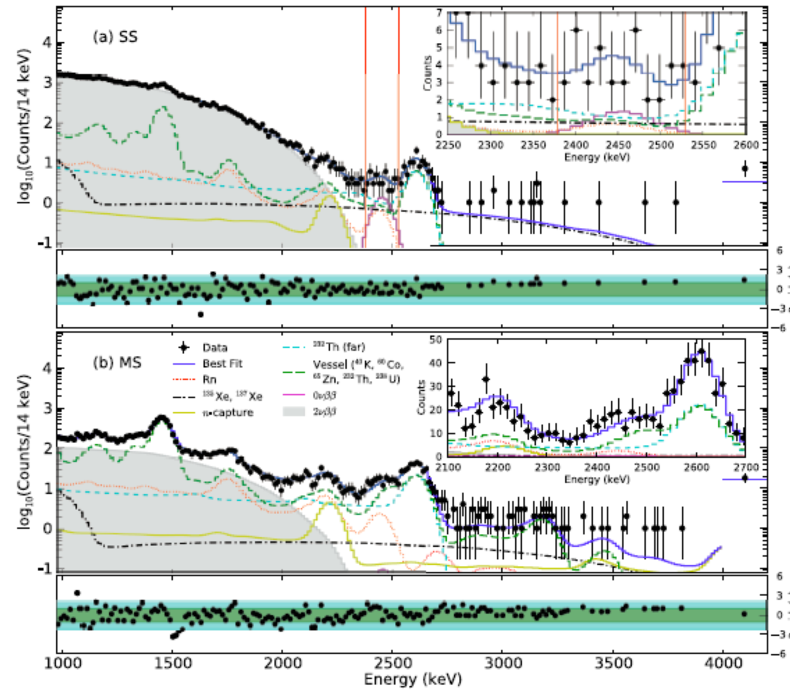


KamLAND-Zen (Japan)
Xe-doped liquid scintillator
383 kg of enriched ^{136}Xe

EXO-200 (USA)
LXe TPC
200 kg of enriched ^{136}Xe

Current State of the Art: ^{136}Xe

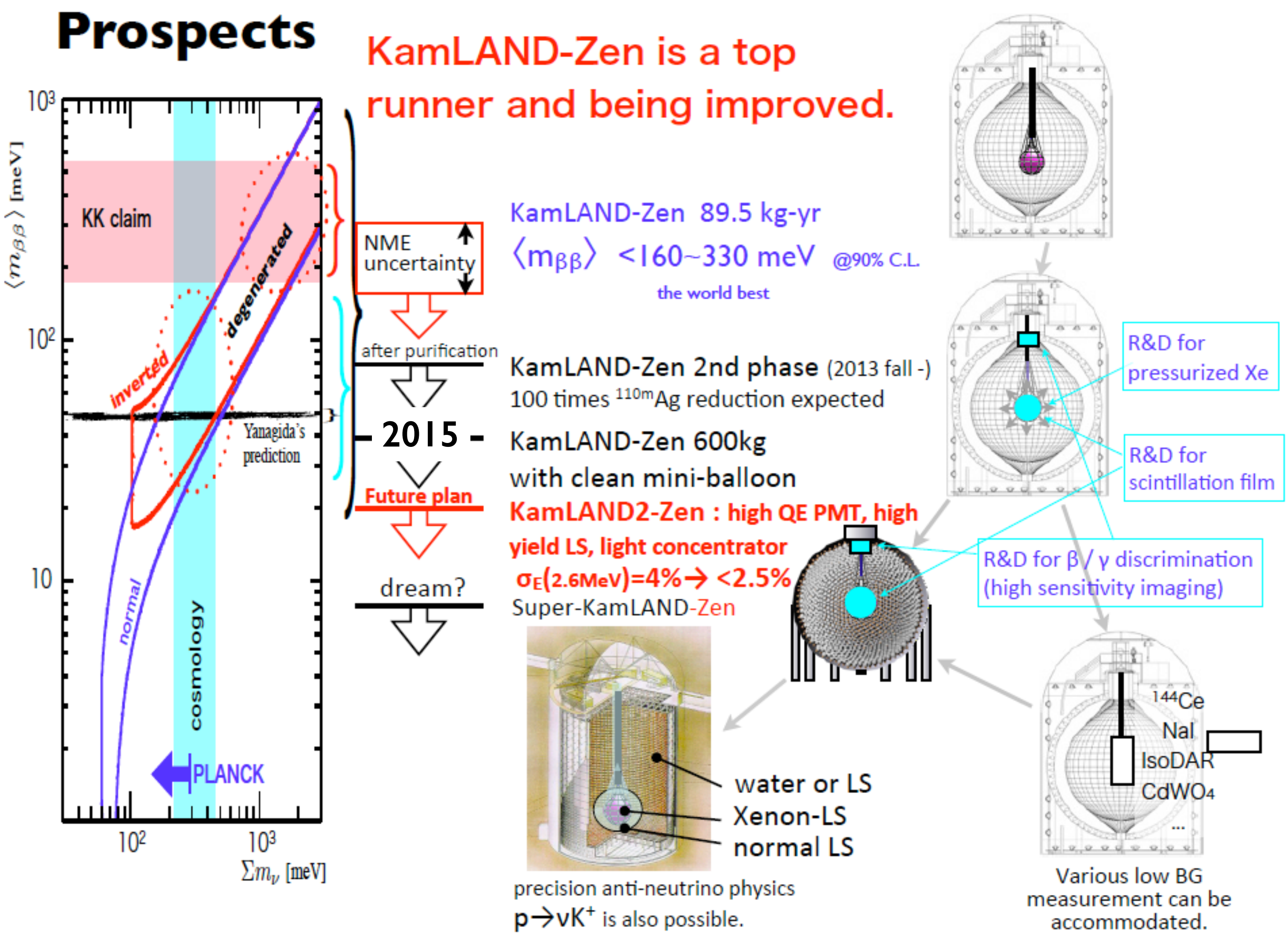




KamLAND-Zen (Japan)
arXiv:1409.0077
$T_{1/2}(^{136}Xe) > 2.6 \times 10^{25}$ years

EXO-200 (USA)
Nature **510**, 229 (2014)
$T_{1/2}(^{136}Xe) > 1.1 \times 10^{25}$ years

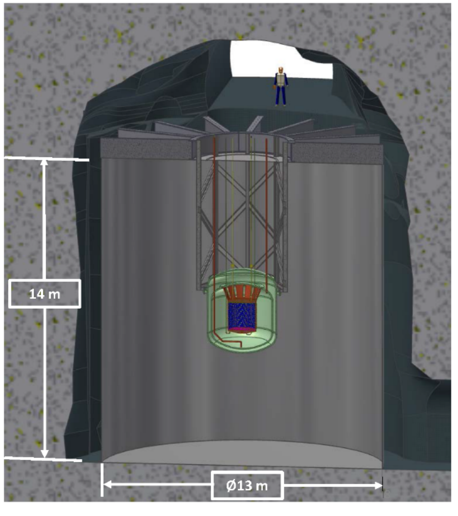
Next-Gen: KamLAND2-Zen



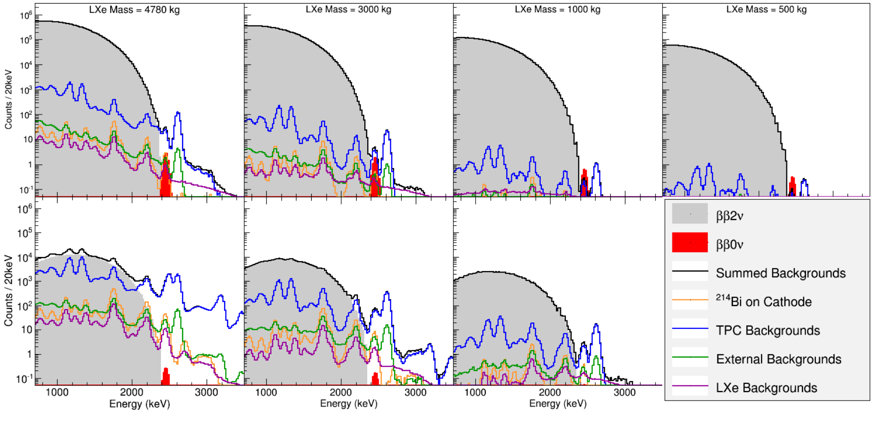
From: K. Inoue

Next-Gen: nEXO

- 5 tonnes of ^{enr}Xe
- nEXO 5 yr 90% CL sensitivity: $T_{1/2} > 6.6 \cdot 10^{27}$ yr
- LXe homogeneous imaging TPC similar to EXO-200:
  - baseline: install at SNOLAB (cosmogenic background reduced wrt EXO-200)
  - simultaneous measurement: energy, spatial extent, location, particle ID
  - Multi-parameter approach improves sensitivity: strengthens proof in case of discovery
  - inverted hierarchy covered with a well proven detector concept
  - possible later upgrade for Ba retrieval/tagging: start accessing normal hierarchy



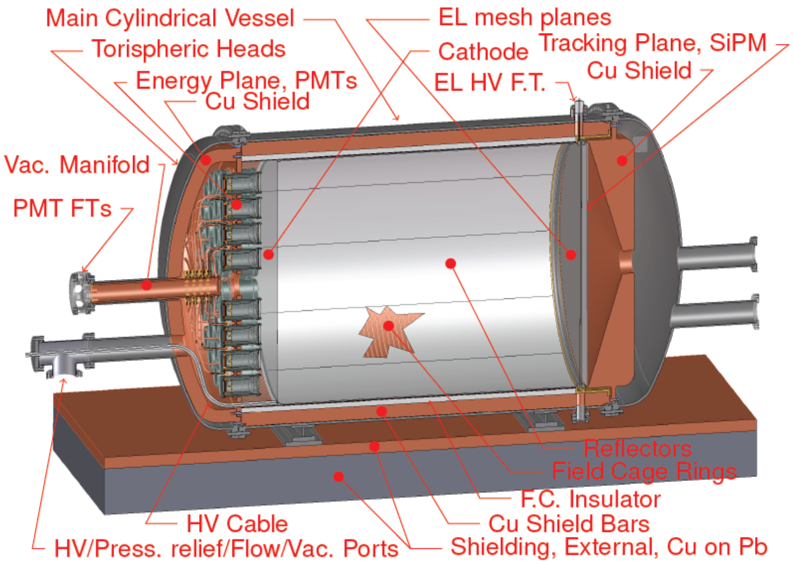
Deeper into fiducial volume



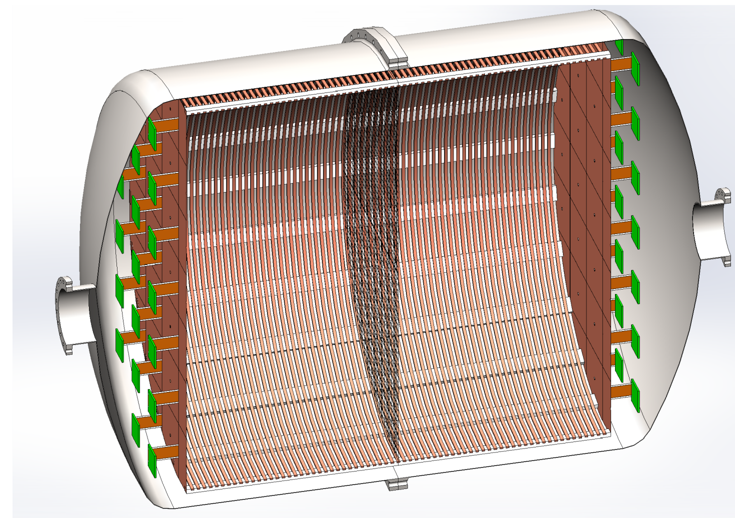
Single-site, Mainly signal, 2ν and 0ν

Multi-site, Mainly background

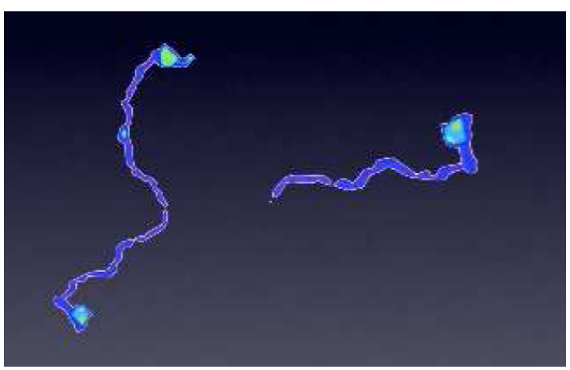
Next-Gen: High-Pressure ^{136}Xe TPC



NEXT (Spain): Electro-luminescence HPXe TPC
10 kg (2015), 100 kg (2017), to tonne

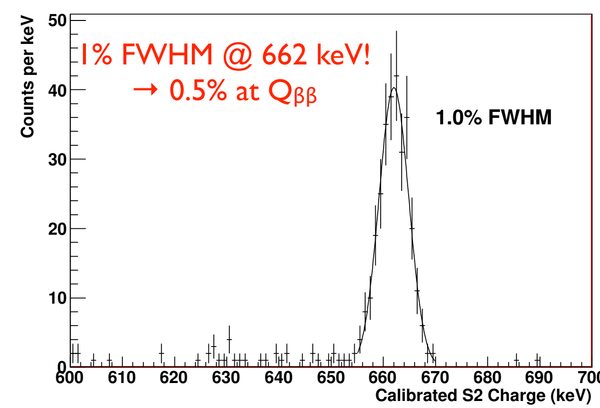


PANDA-X III (China): Electron HPXe TPC
200 kg (2017) to 1 tonne

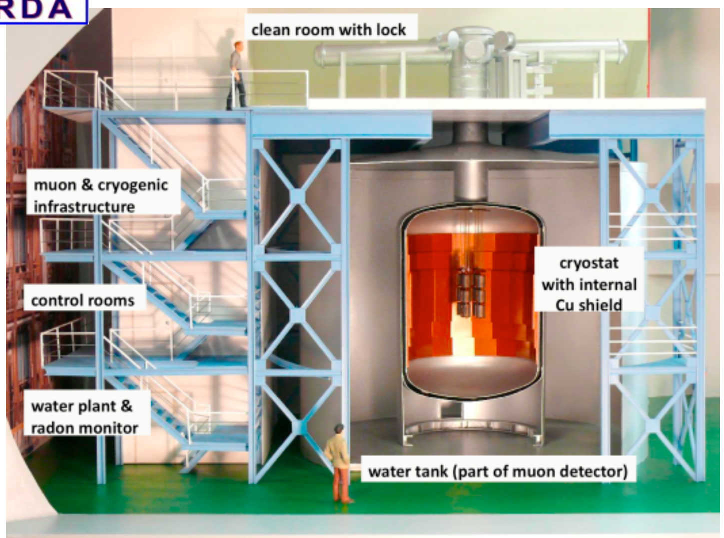


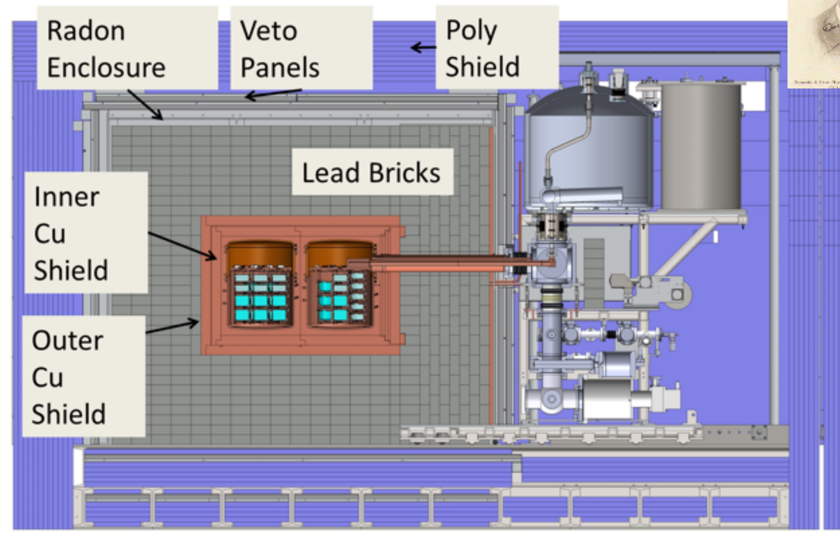
Key features:

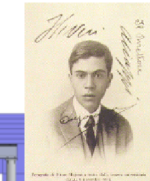
- Event topology (background suppression, kinematics)
- Good energy resolution (significantly better than LXe)



Current State of the Art: ^{76}Ge



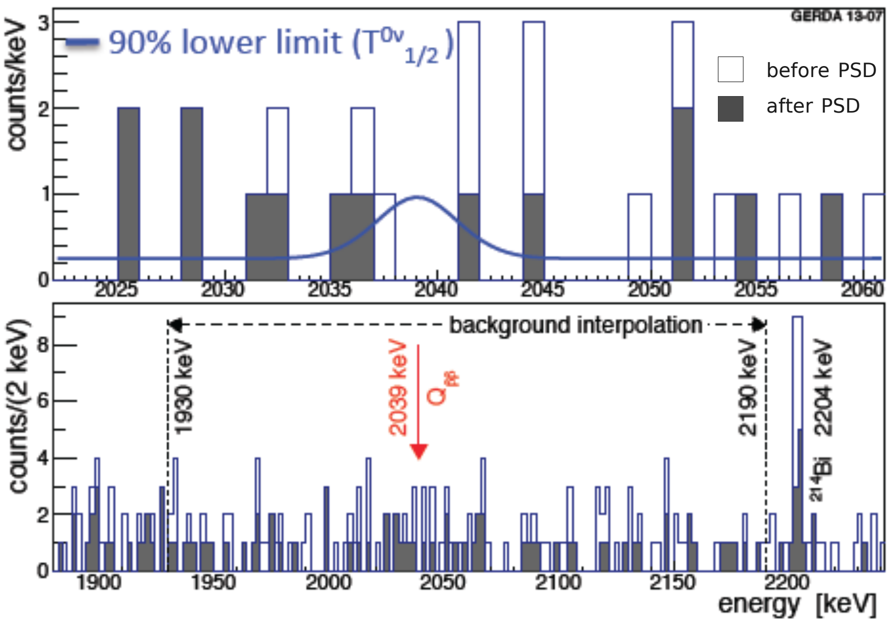




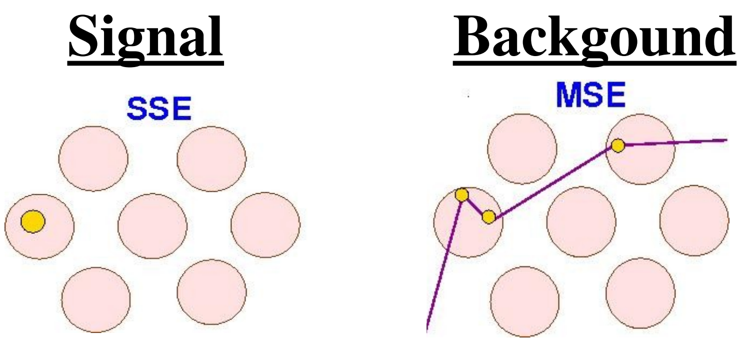
GERDA (Italy)
Enriched HPGe array
LAr active shield
18 kg of enriched ^{76}Ge (Phase I)
40 kg of enriched ^{76}Ge (Phase II)

MAJORANA DEMONSTRATOR (USA)
Enriched HPGe array
High-purity electroformed Cu shield
30 kg of enriched ^{76}Ge
15 kg of natural ^{76}Ge

GERDA Phase I Results



- **Anti-coincidence** with **the muon veto**
- **Anti-coincidence between detectors:** suppression of Multi Site Events (**MSE**) respect to Single Site Events (**SSE**)
- **Pulse shape discrimination** (**PSD**)



$T^{0\nu}_{1/2} > 2.1 \cdot 10^{25}$ yr @ 90% C.L. (Frequentist)

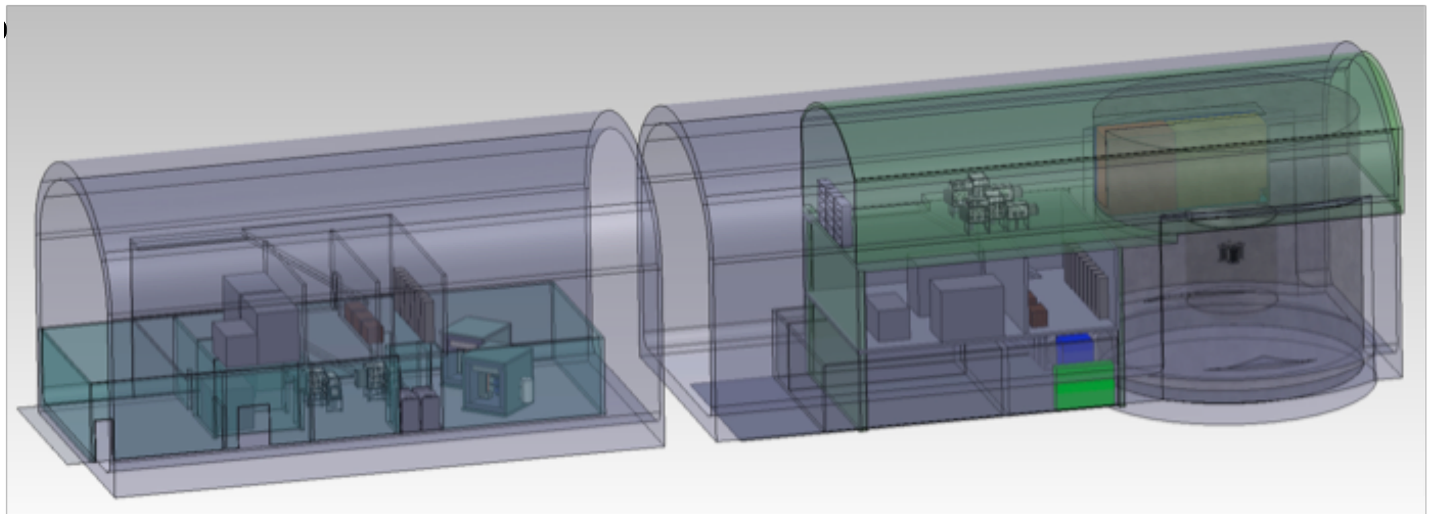
$T^{0\nu}_{1/2} > 3.0 \cdot 10^{25}$ yr @ 90% C.L. (GERDA+IGEX+HdM)

Inconsistent with controversial discovery claim [PL **B586**, 184 (2004)]

GERDA Collaboration, PRL 111 (2013) 122503
Eur. Phys. J. C (2014) 74:2764

Future ^{76}Ge Experiment

- MAJORANA and GERDA are working towards the establishment of a single international ^{76}Ge $0\nu\beta\beta$ collaboration
- Envision a phased, stepwise implementation;
  e.g. 250 → 500 → 1000 kg
  5 yr 90% CL sensitivity: $T_{1/2} > 3.2 \cdot 10^{27}$ yr
  10 yr 3σ discovery: $T_{1/2} \sim 3 \cdot 10^{27}$ yr
- Moving forward predicated on *demonstration* of projected backgrounds by MJD and/or GERDA

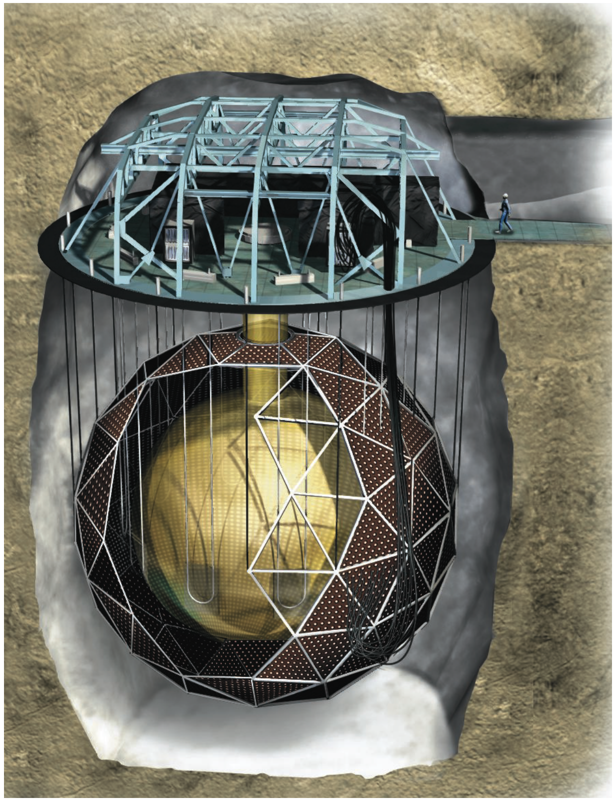


Compact shield | Cryogenic shield

J.F. Wilkerson

^{130}Te: SNO+

SNO+ will replace SNO D_2O with 780 tonnes of LAB, loaded with ^{nat}Te

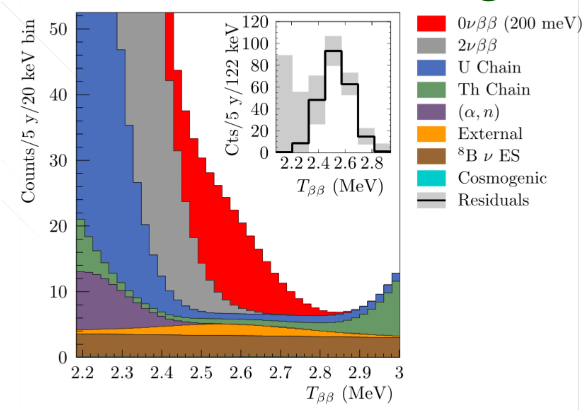


Phase I (2017-): 160 kg ^{130}Te (fiducial volume)

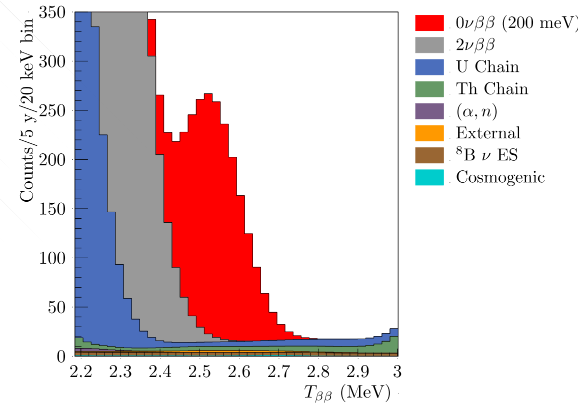
- Scintillator running begins mid-2016
- 0.3% Te loading begins early 2017

Phase II: 2.2 tonnes ^{130}Te

- 3% loading of Te (already demonstrated)
- Increased light yield (PMT upgrade, wavelength shifter)
- Containment bag for Te fiducial volume



SNO+ Phase I



SNO+ Phase II

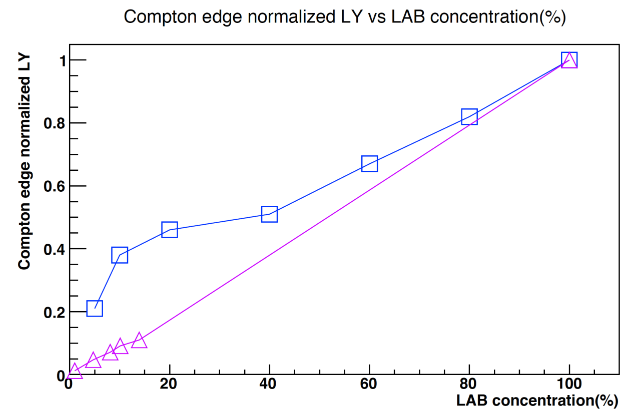
THEIA: multi-purpose ν detector

G.D. Orebi Gann

Concept paper: arXiv:1409.5864

THEIA: multi-purpose ν detector

G.D. Orebi Gann



Light yield as a function of LS fraction, D. Jaffe et al., BNL

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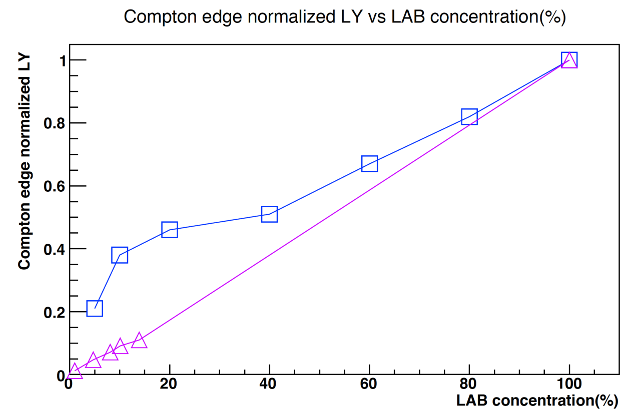
THEIA: multi-purpose ν detector

G.D. Orebi Gann



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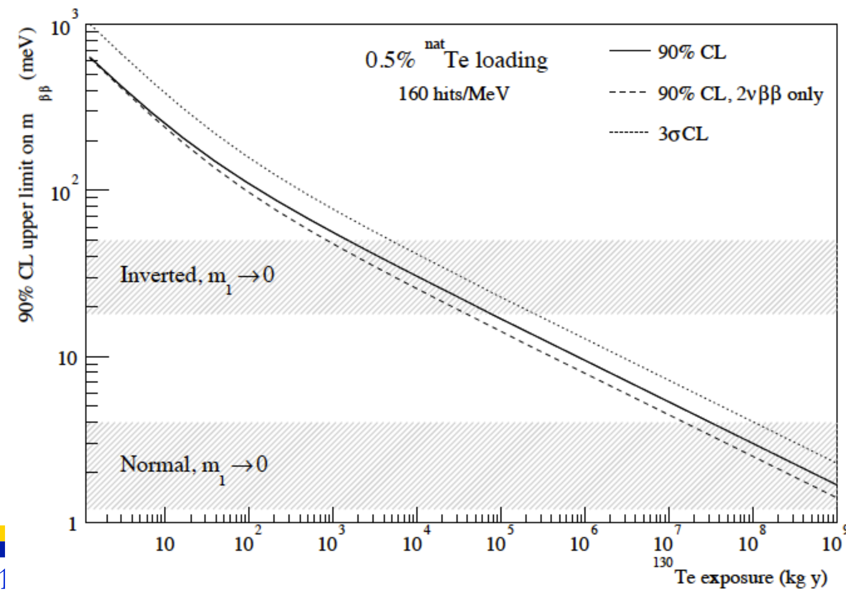

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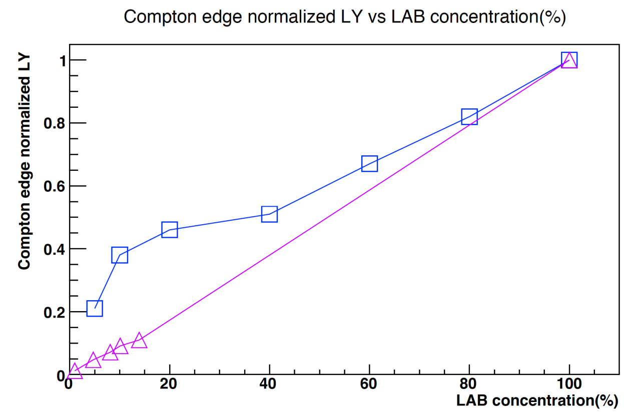

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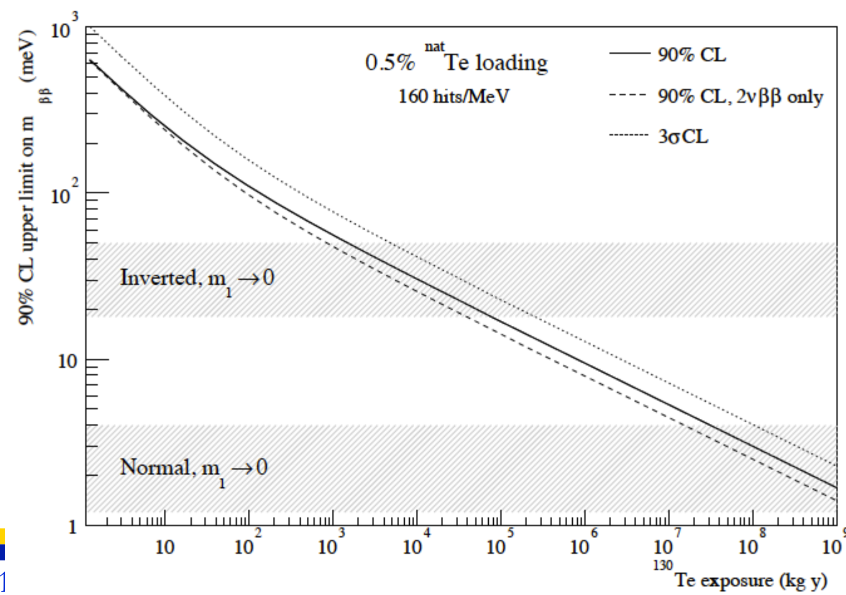


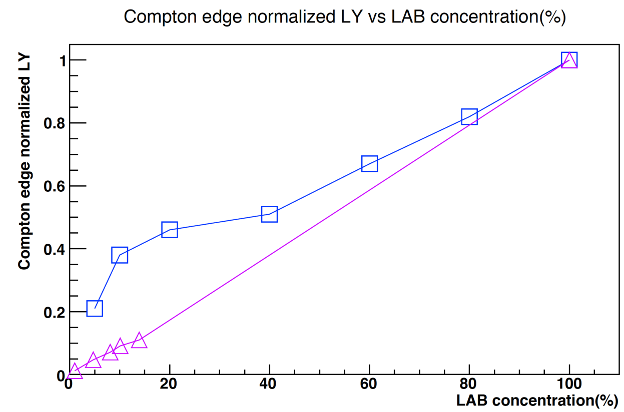
⇛ 3σ discovery for $m_{\beta\beta}$=15meV in 10 yrs

Concept paper: arXiv:1409.5864

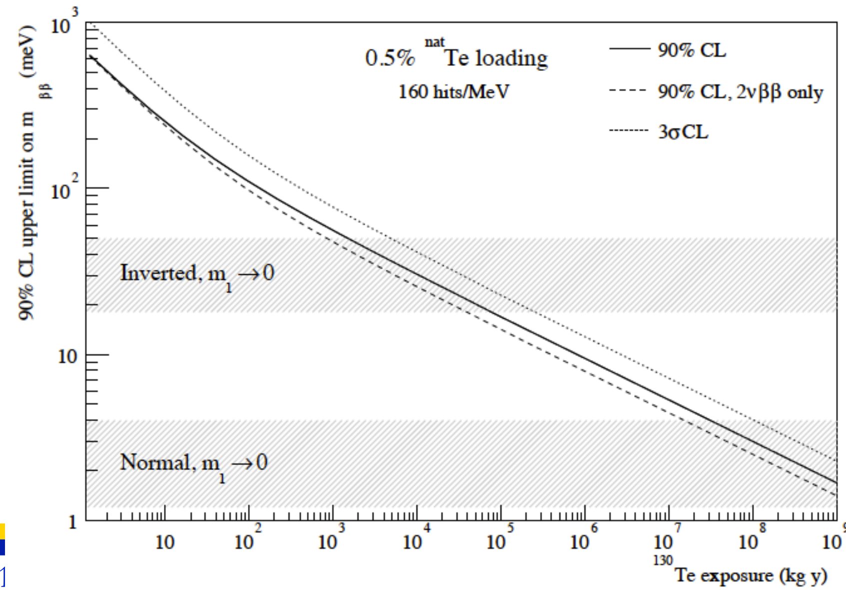
THEIA: multi-purpose ν detector

G.D. Orebi Gann

Water-based liquid scintillator: separation of Cherenkov and scintillation signals



Light yield as a function of LS fraction, D. Jaffe et al., BNL



⇛ 3σ discovery for $m_{\beta\beta}$=15meV in 10 yrs

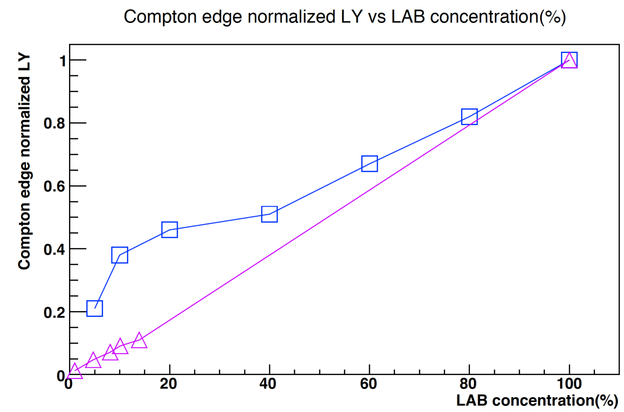
Concept paper: arXiv:1409.5864

THEIA: multi-purpose ν detector

G.D. Orebi Gann

Water-based liquid scintillator: separation of Cherenkov and scintillation signals

Reject dominant background from solar neutrinos



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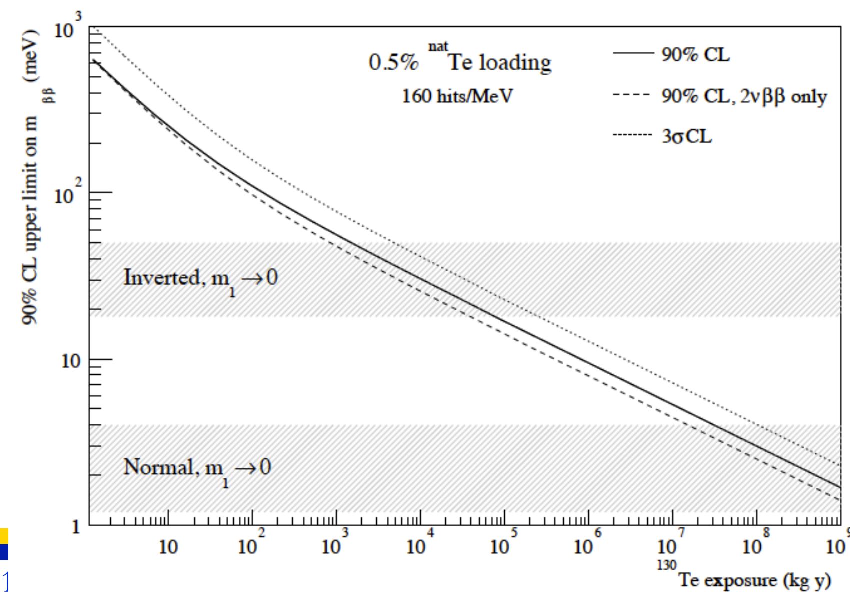

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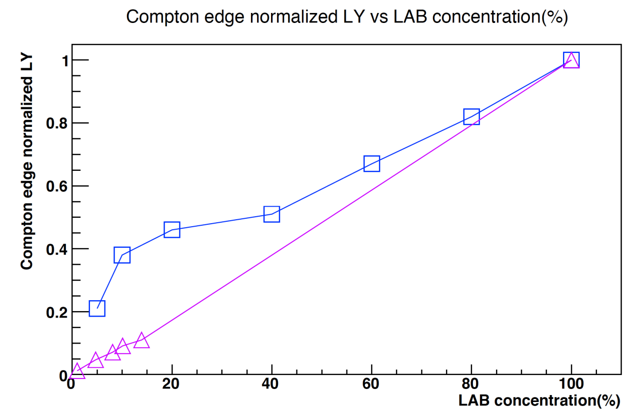
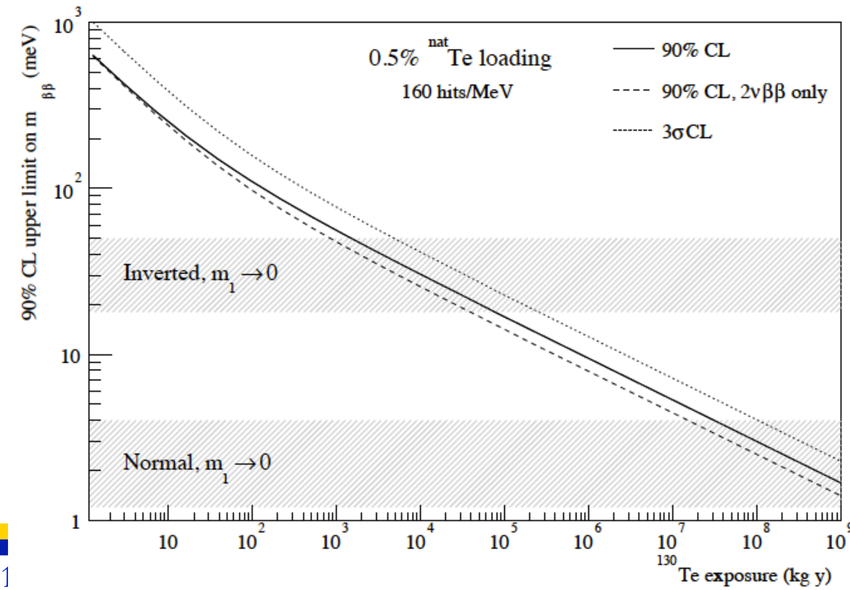


Light yield as a function of LS fraction, D. Jaffe et al., BNL

50kt detector
0.5% loading ^{nat}Te
50t ^{130}Te in fid vol



⇛ 3σ discovery for $m_{\beta\beta}$=15meV in 10 yrs

Concept paper: arXiv:1409.5864

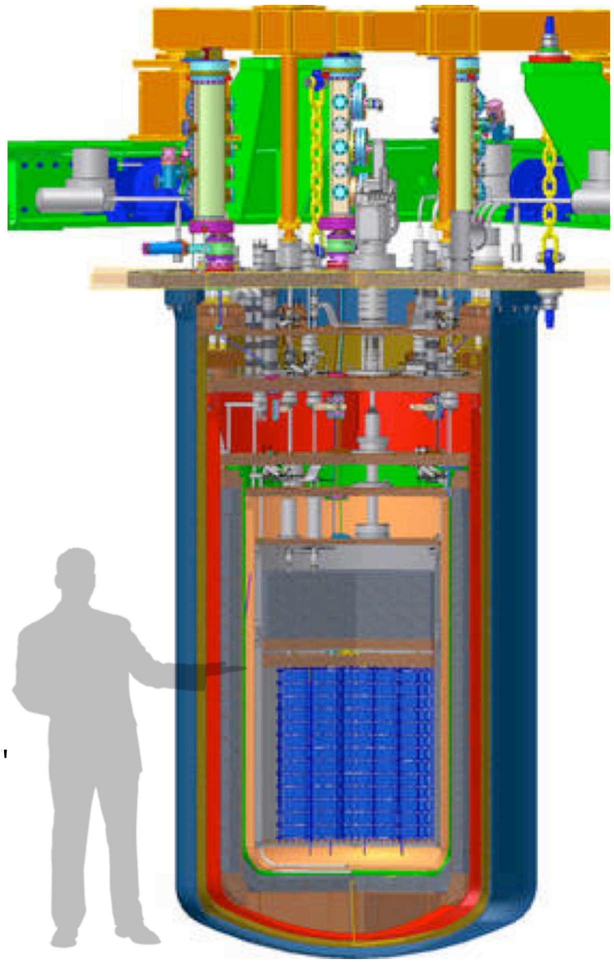
^{130}Te: CUORE

Array of 988 TeO_2 cryogenic bolometers

- **19** towers suspended in a cylindrical structure
- **13** levels, **4** crystals each
- 5x5x5 cm^3 (750g each)
- ^{130}Te: 33.8% natural isotope abundance

750 kg TeO_2 => 200 kg ^{130}Te

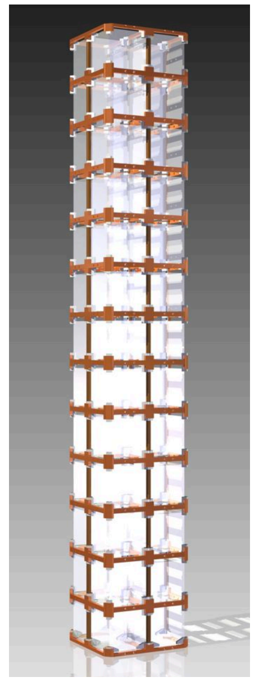
- New pulse tube refrigerator and cryostat:
  - Coldest m^3 in Universe (~10 mK)
- Radio-purity techniques and high resolution achieve low backgrounds
- Joint venture between Italy (INFN) and US (DOE, NSF)
- Under construction (expected start of operations by end of 2015)
- Expect energy resolution of 5 keV FWHM and background of ~0.01 counts/(kg*keV*year) in ROI



The CUORE Program

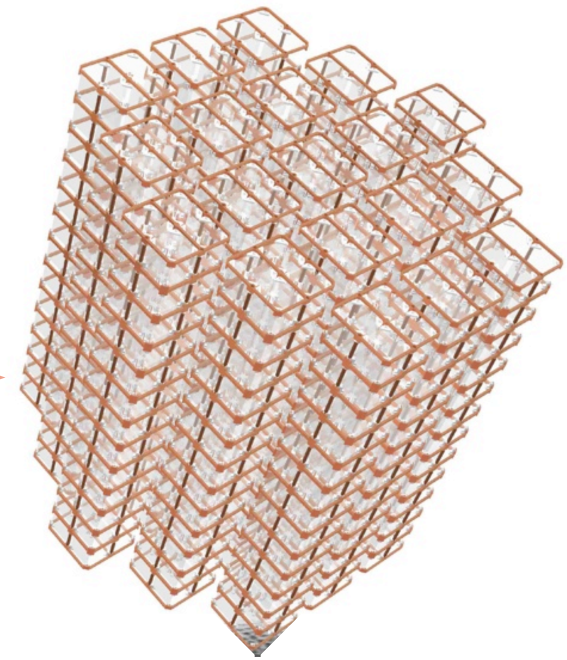
Cuoricino
2003–2008
11 kg ^{130}Te

Complete



CUORE-0
2013–2015
11 kg ^{130}Te

Operating

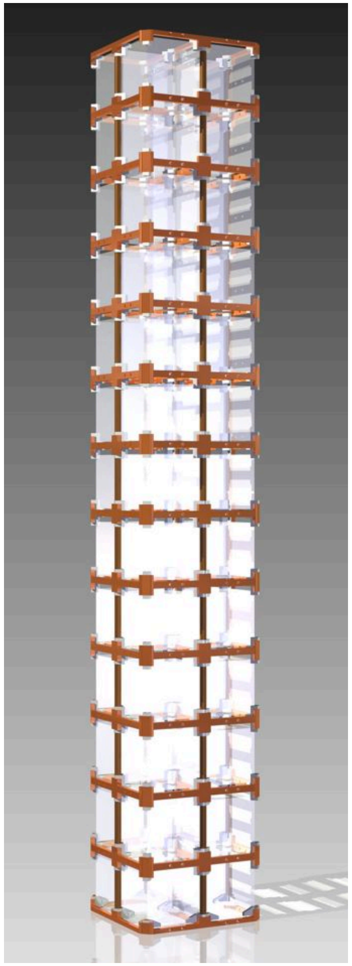


CUORE
2015–2020
206 kg ^{130}Te

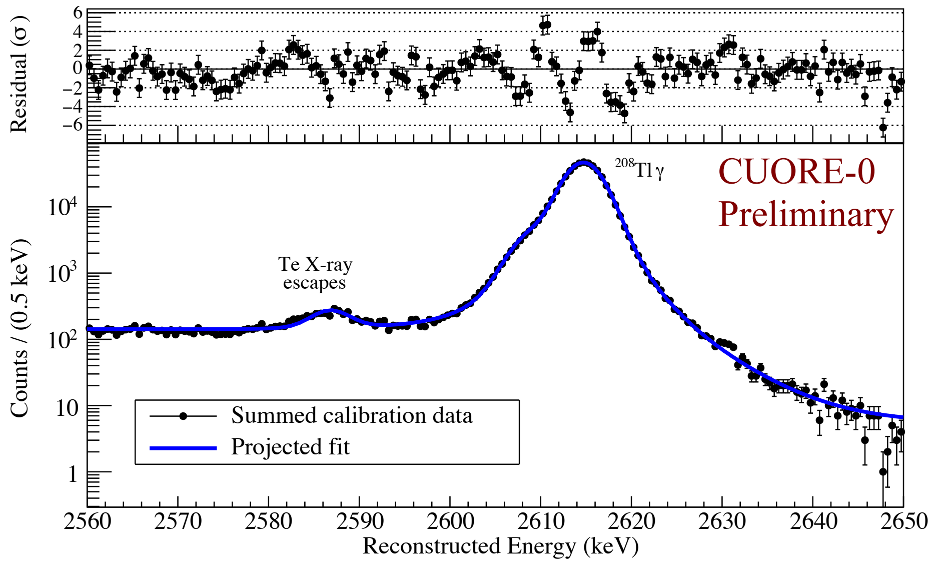
Under Construction

CUORE-0

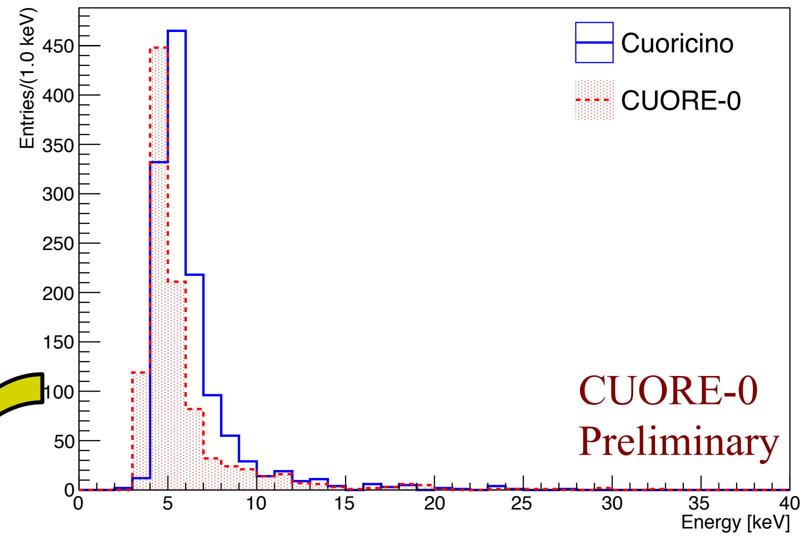
- First tower from the CUORE detector assembly line
- 52 TeO_2 crystals, total mass = 39 kg TeO_2 = 10.9 kg ^{130}Te
- Purpose:
  1. Commission assembly line
  2. Run as standalone experiment while CUORE is being constructed, with aim of surpassing Cuoricino
  3. Validate CUORE detector design
  4. Provide test bed for developing DAQ & analysis framework for CUORE
- Operating in former Cuoricino cryostat since March 2013



Energy Resolution



Bolometer-dataset FWHMs @ 2615 keV

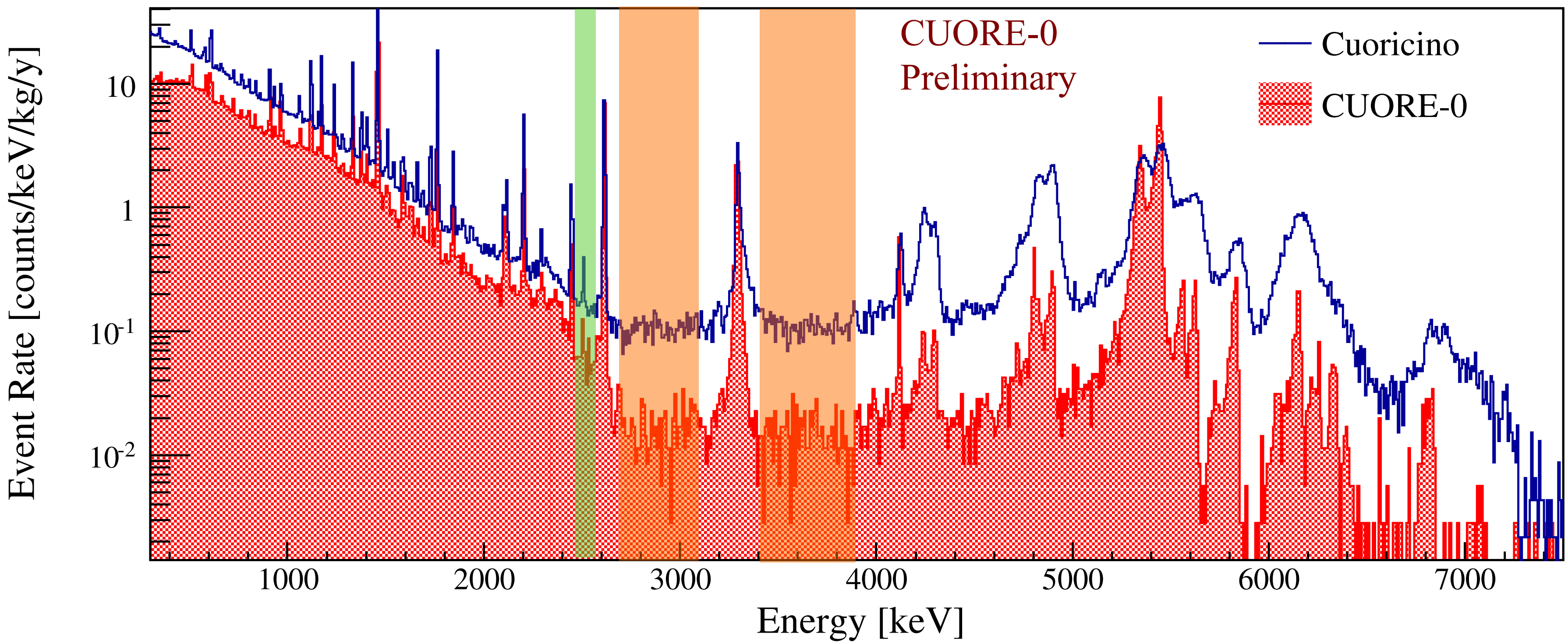


Weight FWHMs
by corresponding
physics exposure

	FWHM harmonic mean (keV)	FWHM dist RMS (keV)
Cuoricino	5.8	2.1
CUORE-0	4.9	2.9

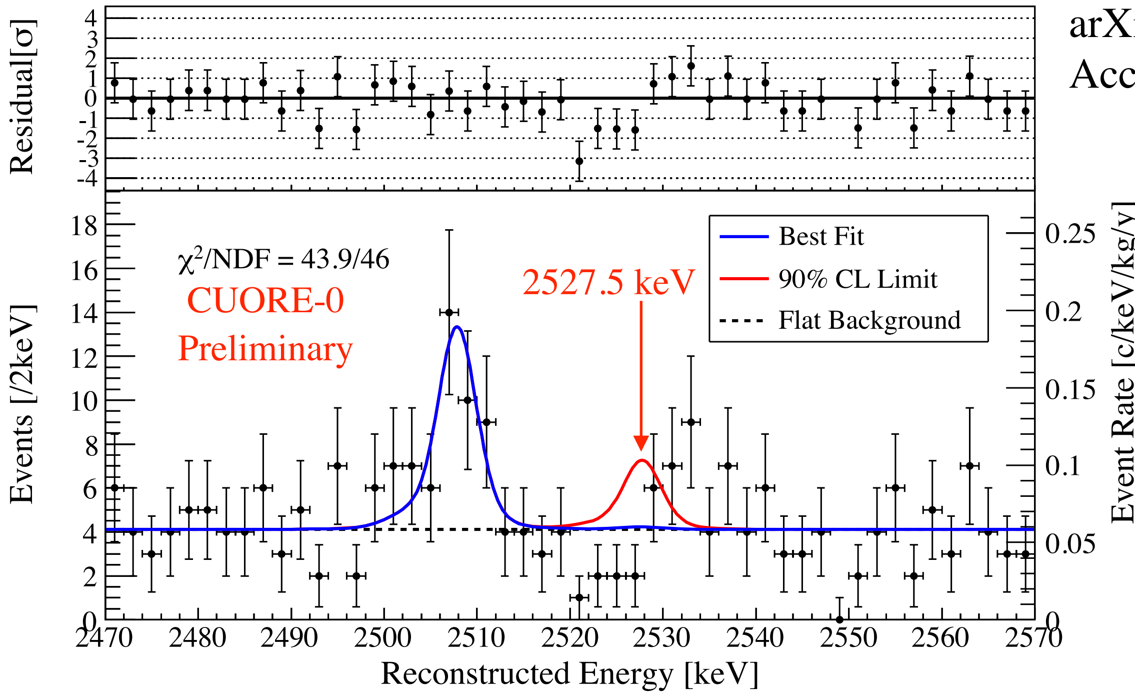
- We evaluate the energy resolution for each bolometer and dataset by fitting the ^{208}Tl photopeak in the calibration data
- We achieved the 5 keV resolution goal of CUORE!

Backgrounds



Experiment	Background rate (counts/keV/kg/y)	
	$0\nu\beta\beta$ decay region	Alpha region (excl. peak)
Cuoricino	0.169 ± 0.006	0.110 ± 0.001
CUORE-0	0.058 ± 0.004	0.016 ± 0.001

CUORE-0 Results



arXiv:1504.02454
Accepted to PRL

Fitted background:	0.058 ± 0.004 (stat.) ± 0.002 (syst.) counts/keV/kg/yr
Best-fit decay rate:	$\Gamma^{0\nu\beta\beta}(^{130}\mathrm{Te}) = 0.007 \pm 0.123\ (\mathrm{stat.}) \pm 0.012\ (\mathrm{syst.}) \times 10^{-24}\ \mathrm{yr}^{-1}$

90% C.L. limits (Bayesian):

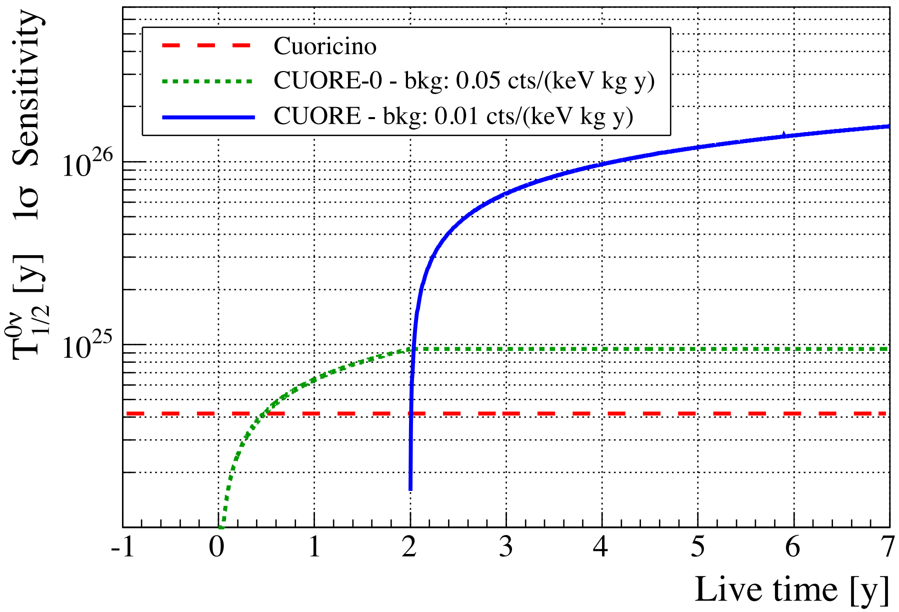
$$\Gamma^{0\nu\beta\beta}(^{130}\mathrm{Te}) < 0.25 \times 10^{-24}\ \mathrm{yr}^{-1}$$

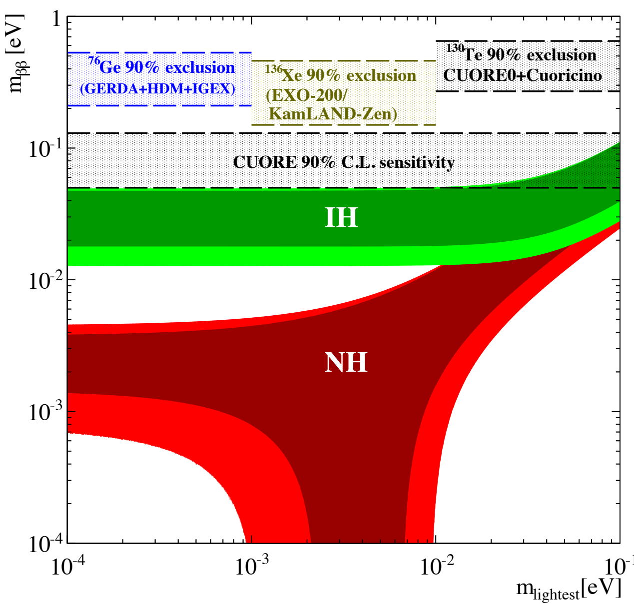
$$T_{1/2}^{0\nu\beta\beta}(^{130}\mathrm{Te}) > 2.7 \times 10^{24}\ \mathrm{yr}$$

CUORE-0+Cuoricino limit: $T_{1/2}^{0\nu\beta\beta}(^{130}\mathrm{Te}) > 4.0 \times 10^{24}\ \mathrm{yr}$ (90% C.L.)

CUORE Status and Sensitivity

- Detector: all towers assembled, in underground storage
- Cryostat and dilution unit: commissioning, reached 6 mK base temperature
- Expect to start operations by the end of the year
- 5-year sensitivity: $T_{1/2}(^{130}Te) > 9.5\times10^{25}$ years, $m_{\beta\beta} < 52\text{-}120$ meV

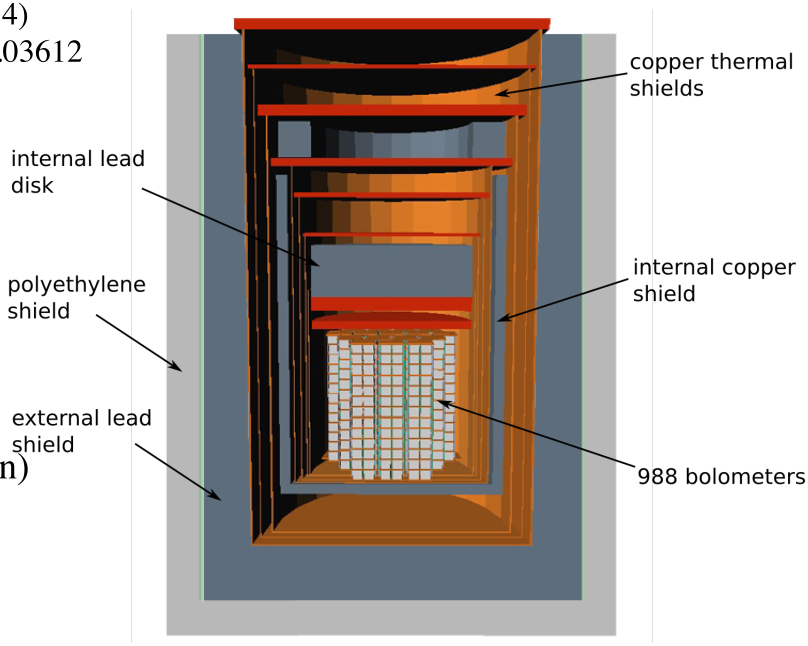




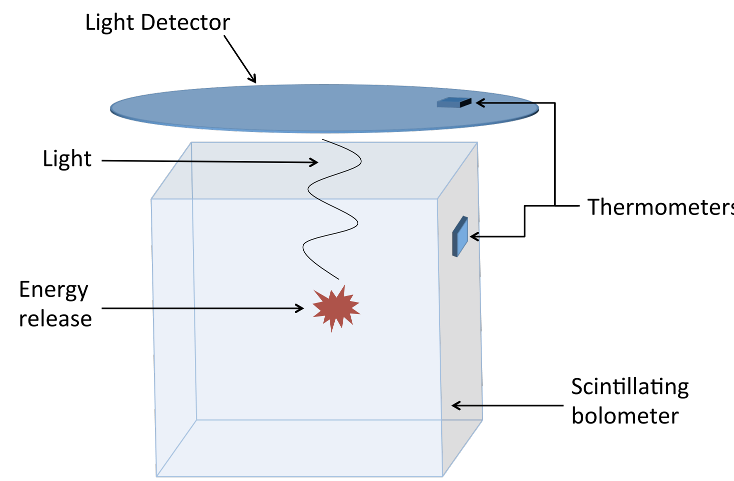
CUORE Upgrade with Particle ID (CUPID)

R. Artusa et al., Eur.Phys.J. **C74**, 3096 (2014)
White papers: arXiv:1504.03599 & arXiv:1504.03612

- Next-generation bolometric tonne-scale experiment
- Based on the CUORE design, CUORE cryogenics
- 988 enriched (90%) crystals, PID with light detection
  - 4 crystals considered:
    - ☞ TeO_2 : phonons + Cherenkov detector
    - ☞ Options: ZnSe, $ZnMoO_4$, $CdWO_4$ (phonons+scintillation)



- Sensitivity to entire IH region
    - ☞ CUORE geometry and background model
    - ☞ 99.9% α rejection @ >90% signal efficiency
    - ☞ 5 keV FWHM resolution
    - ☞ Challenge: nearly zero background measurement: (ton-year)
    - ☞ Half-life sensitivity (2-5)×10^{27} years in 10 years (3σ)
    - ☞ $m_{\beta\beta}$ sensitivity 6-20 meV (3σ)

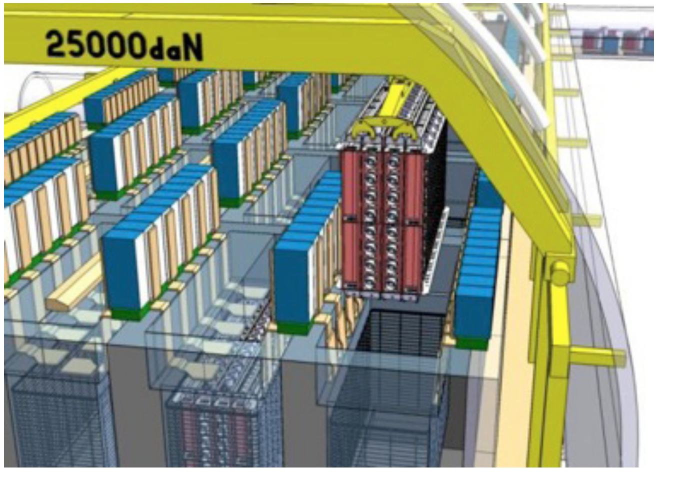


Subject of focused R&D effort in next 2-3 years

^{82}Se: SuperNEMO

- Thin foil with tracking and calorimeter, based on successful NEMO3 detector.
- Planar and modular design: ~ 100 kg of enriched isotopes (20 modules × ~5-7 kg)
- Starting with single Demonstrator module, (7 kg of ^{82}Se) to show scalability
- $T_{0\nu 1/2} > 6.5 \times 10^{24}$ y → ⟨mν⟩ < 0.20 - 0.40 eV @ (90 % C.L.)
- SuperNEMO
  - 100 kg of ^{82}Se running for 5 years
  - $T_{0\nu 1/2} > 1 \times 10^{26}$ y (90 % C.L.) ⟨mν⟩ < 40-100 meV
  - $T_{0\nu 1/2} = 2 \times 10^{25}$ y (5σ)

20 Modules 100 kg



Demonstrator (1 module):

Source (40 mg/cm^2) 4 x 3 m^2

Tracking : drift chamber ~2000 cells in Geiger mode

Calorimeter: scintillators + PMTs

~550 PMTs+scint. blocks

Passive water shield

International $0\nu\beta\beta$ Program

Previous Expts.
$T_{1/2} \sim 10^{24}$ y
(~ 1 eV)
~kg scale

Quasi-degenerate
$T_{1/2} \sim 10^{25}$-10^{26} y
(~100 meV)
30 - 200 kg
~8 expts

1980 - 2007

2007 - 2017

2015 - 2025

J.F. Wilkerson

International $0\nu\beta\beta$ Program

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$T_{1/2} \sim 10^{24}$ y
(~ 1 eV)
~kg scale

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$T_{1/2} \sim 10^{25}$-10^{26} y
(~100 meV)
30 - 200 kg
~8 expts

If $0\nu\beta\beta$ observed

Program to study multiple $0\nu\beta\beta$ isotopes, using various techniques

200-500 kg scale

1980 - 2007

2007 - 2017

2015 - 2025

J.F. Wilkerson

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~8 expts

Inverted hierarchy
$T_{1/2} \sim 10^{27}$-10^{28} y
(~15 meV)
tonne (phased)
~3 experiments
All international in scope
U.S. involvement in ~2

1980 - 2007

2007 - 2017

2015 - 2025

J.F. Wilkerson

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Program to study multiple $0\nu\beta\beta$ isotopes, using various techniques

~ tonne scale

If $0\nu\beta\beta$ Observed

1980 - 2007

2007 - 2017

2015 - 2025

J.F. Wilkerson

International $0\nu\beta\beta$ Program

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(~ 1 eV)
~kg scale

Quasi-degenerate
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(~100 meV)
30 - 200 kg
~8 expts

Inverted hierarchy
$T_{1/2} \sim 10^{27}$-10^{28} y
(~15 meV)
tonne (phased)
~3 experiments
All international in scope
U.S. involvement in ~2

Normal hierarchy
~5 meV
≥10's ton scale

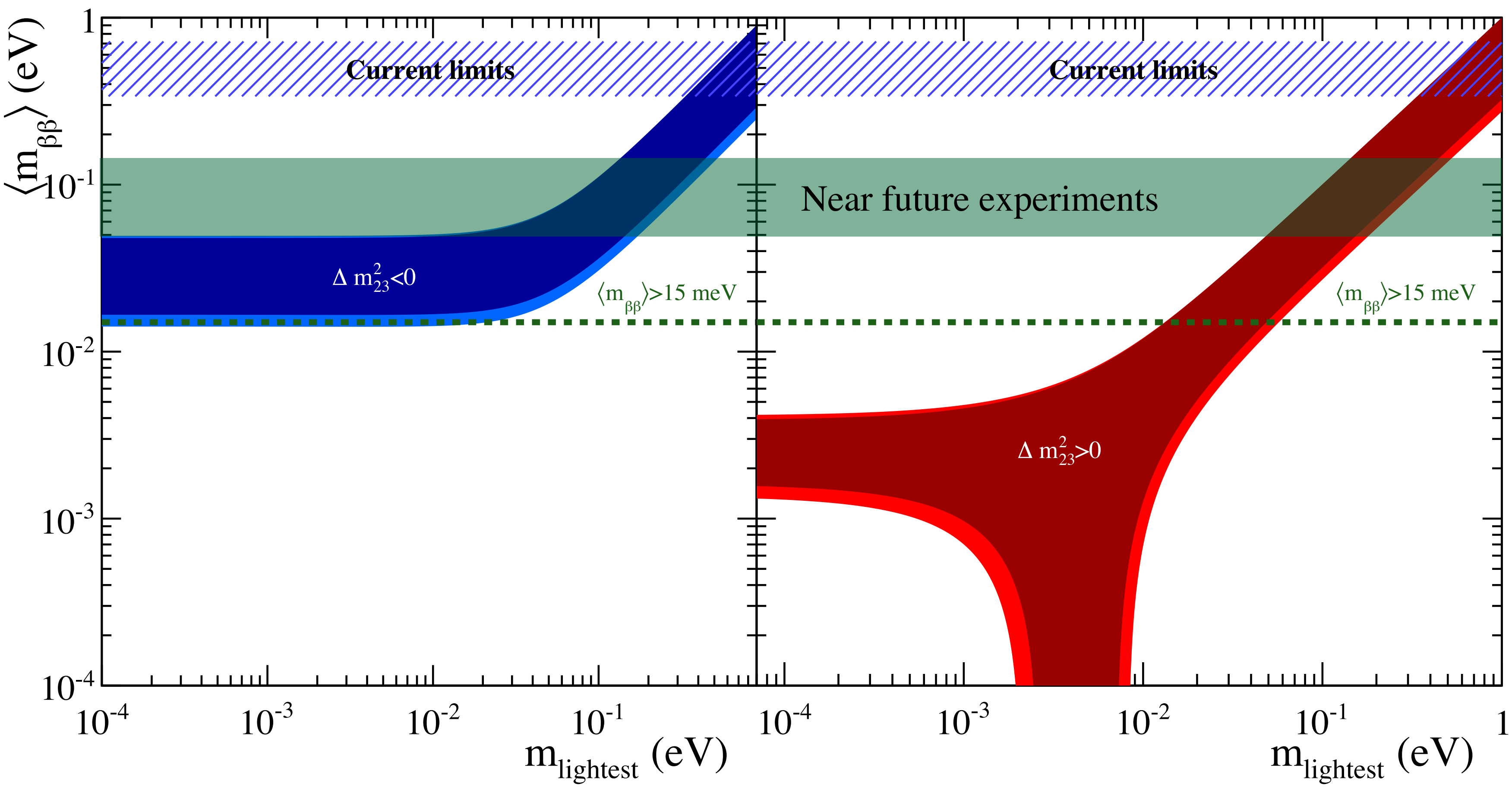
1980 - 2007

2007 - 2017

2015 - 2025

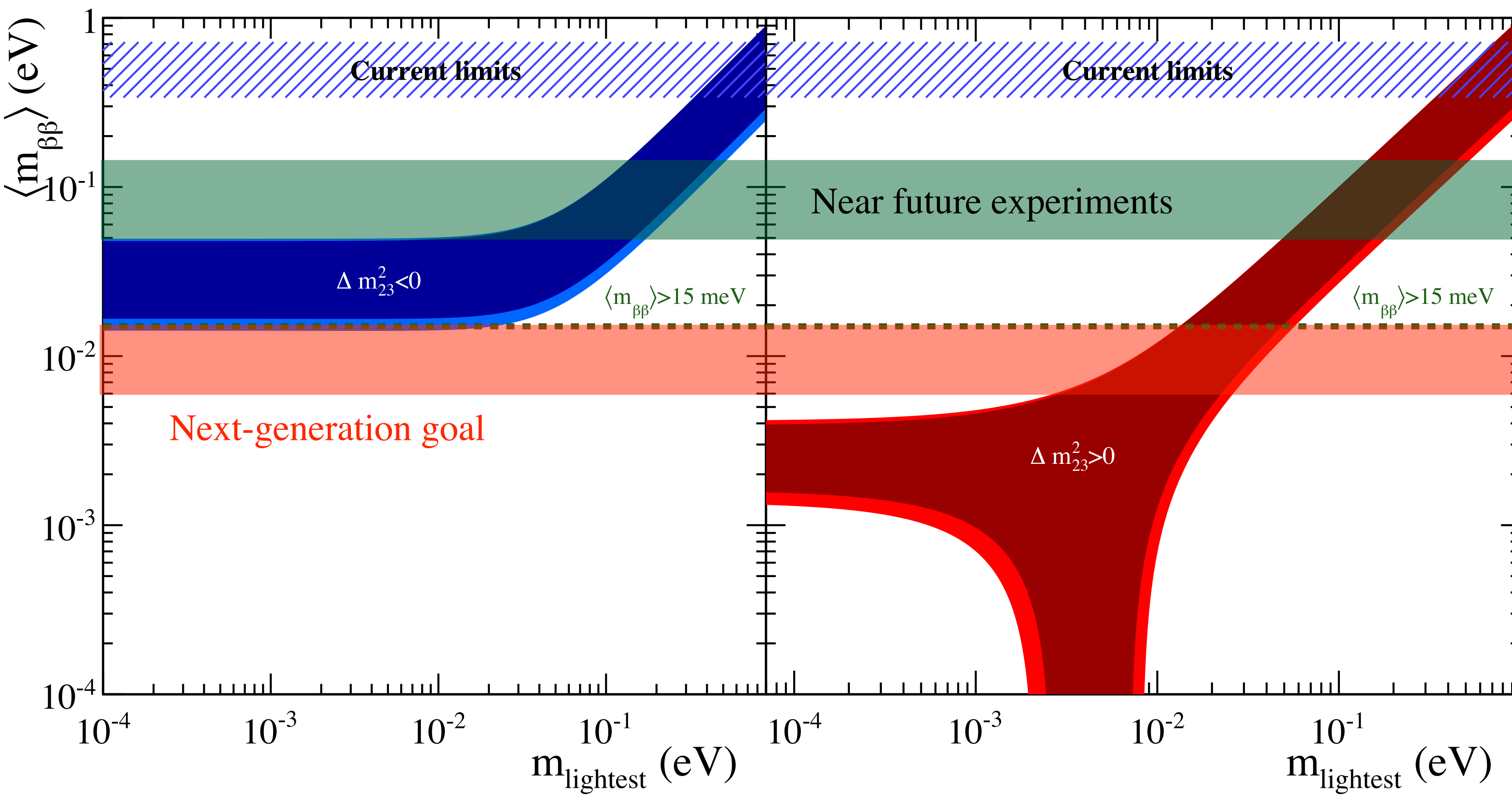
J.F. Wilkerson

DBD and Neutrino Mass



$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

DBD and Neutrino Mass



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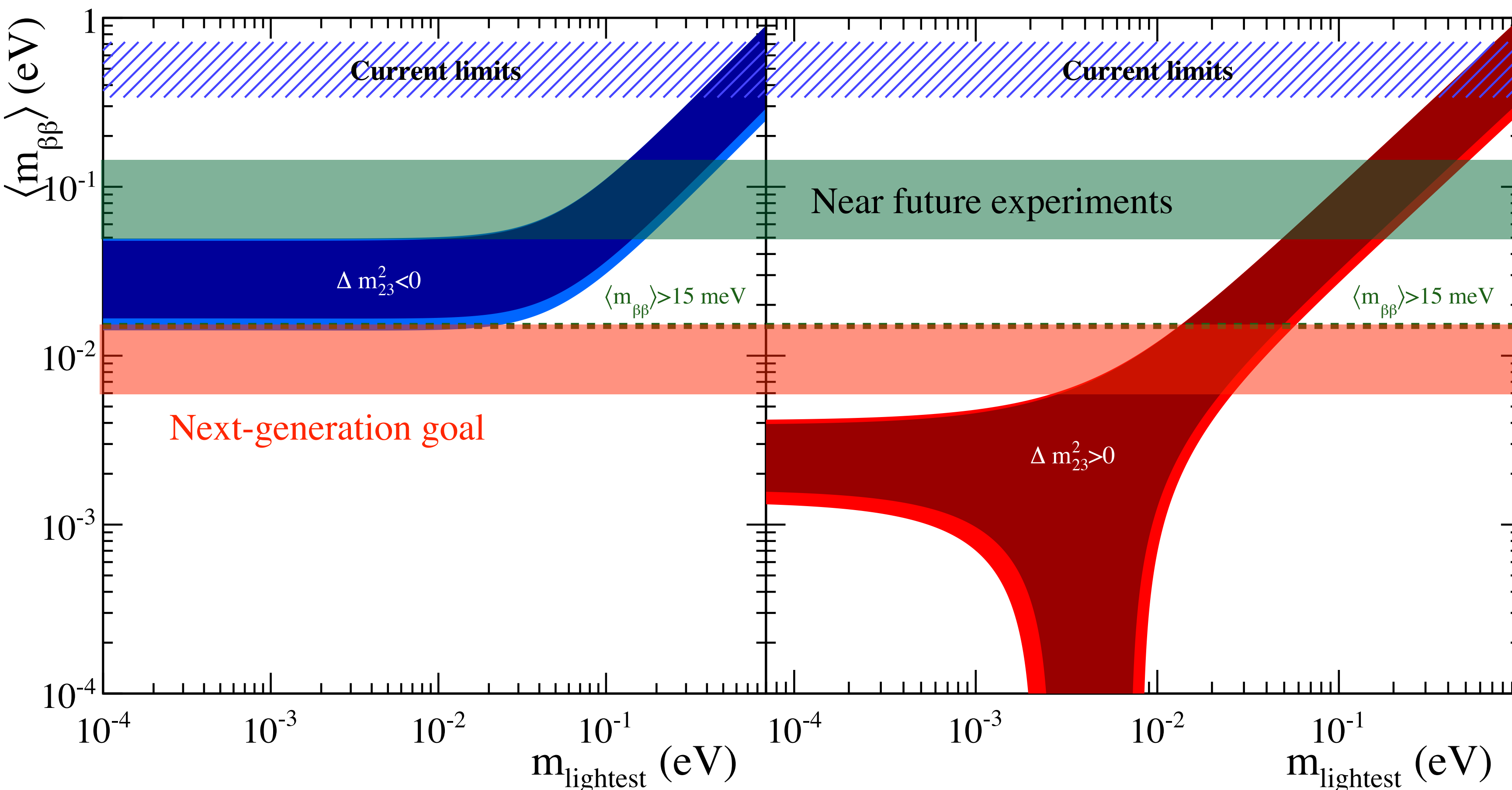
DBD and Neutrino Mass



Exciting future ahead !

$$m_{\beta\beta} = |\sum_i m_i \cdot U_{ie}^2|$$

Many Thanks

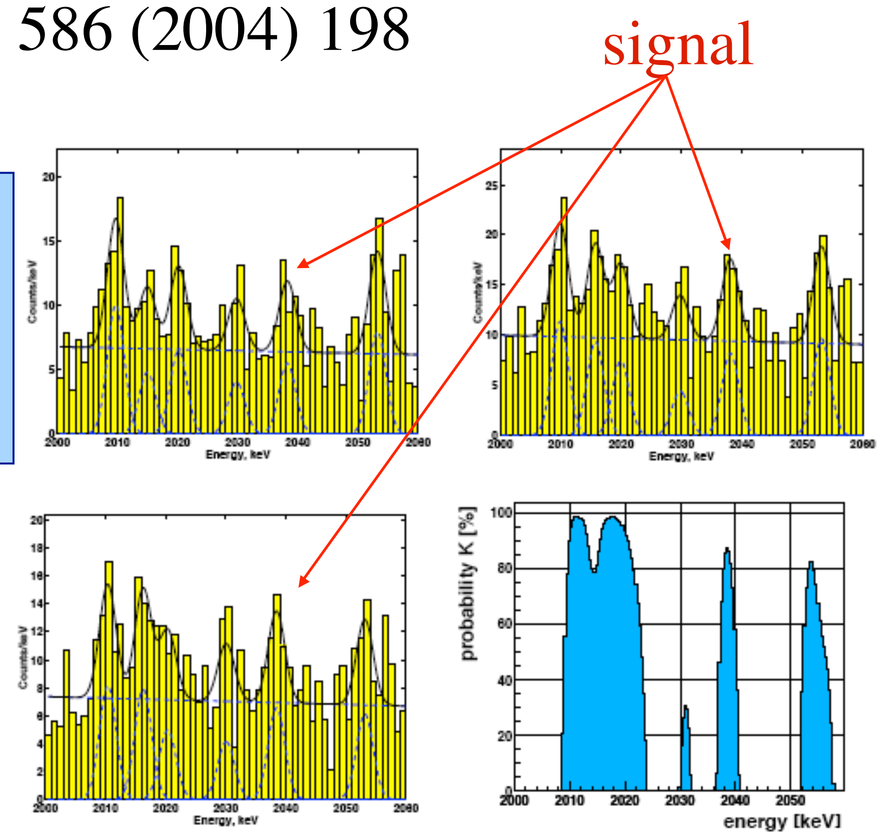
S. Elliot, B. Fujikawa, J.J. Gomez-Cadenas, G. Gratta, X. Ji, J. Klein, G.D. Orebi Gann, B.Schwingenheuer, J.F. Wilkerson, L. Yang, and others

Backup

Possible Evidence: Klapdor et al

- Heidelberg-Moscow Ge experiment
  - 11 kg of enriched ^{76}Ge, 72 kg*y exposure
  - Fraction of the collaboration (KKDC) claim discovery
    - ☞ Klapdor et al., Phys. Lett B 586 (2004) 198

T = (0.7 - 4.2) x 10^{25} years (3σ C.L.)
$m_{\beta\beta}$ = (0.2 - 0.6) eV (3σ C.L.)
$m_{\beta\beta\ best}$ = 0.28 eV
4.2σ claim



Intriguing, but not universally accepted…

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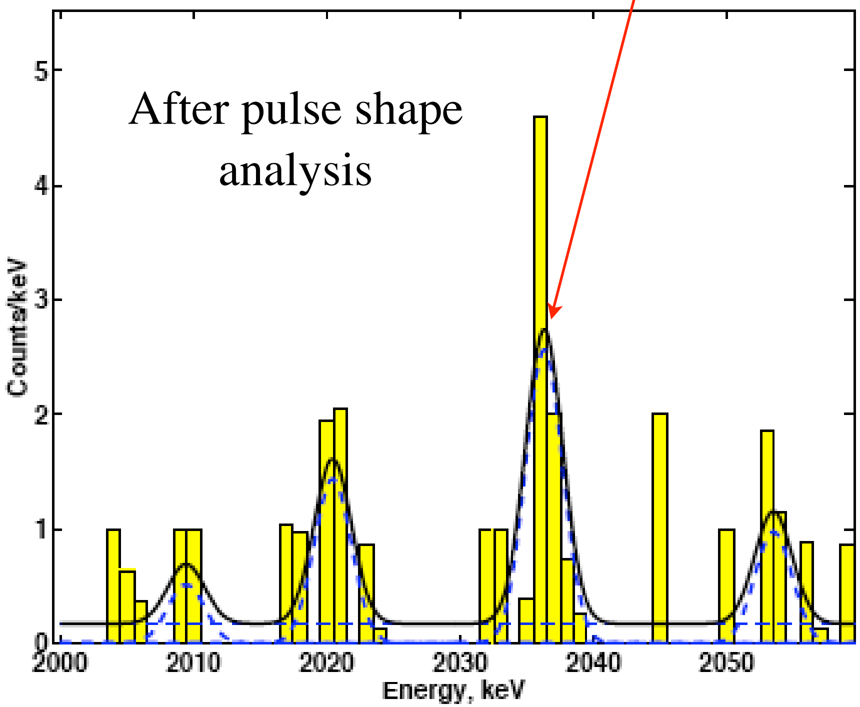
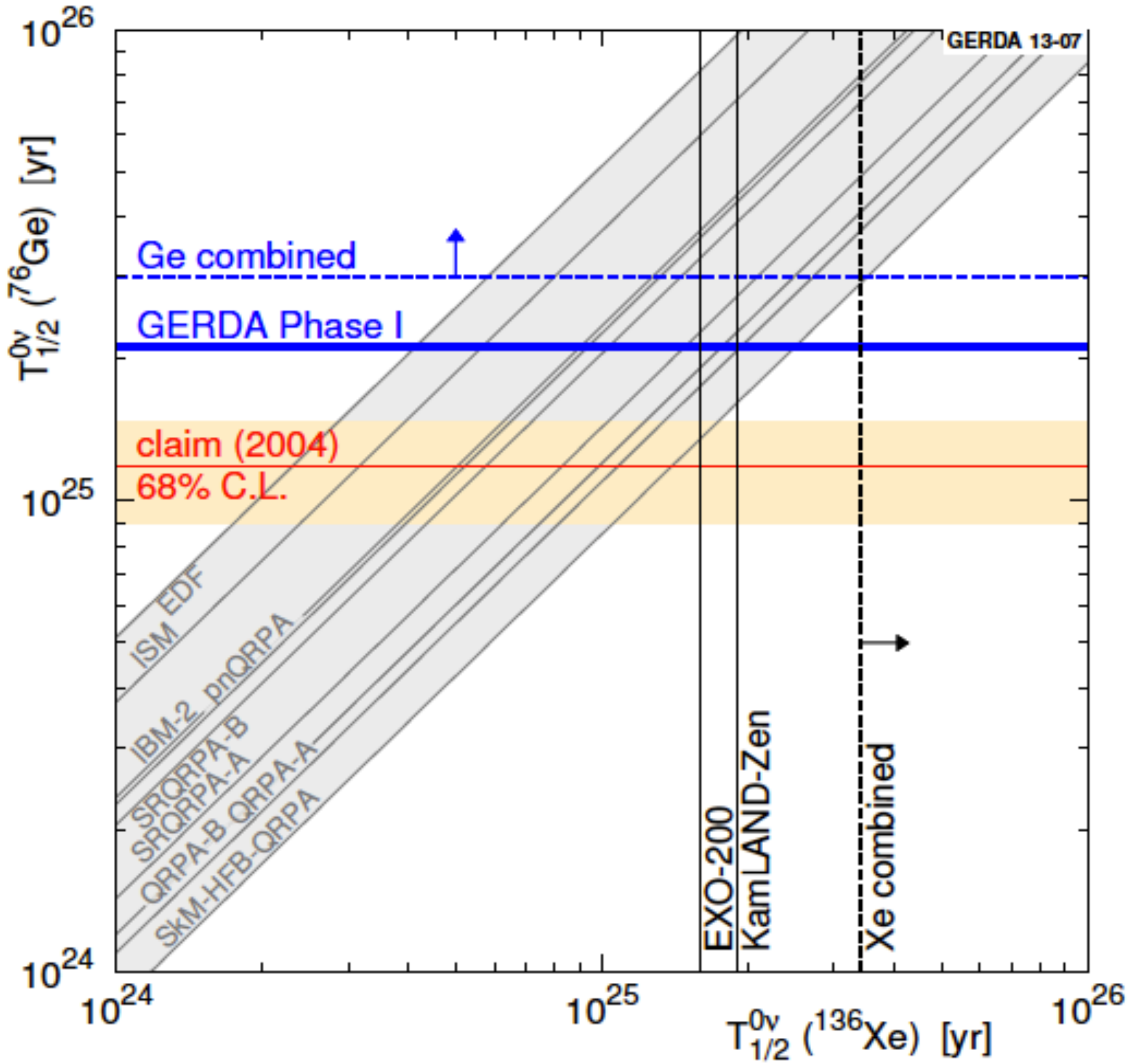
signal



^{76}Ge vs ^{136}Xe

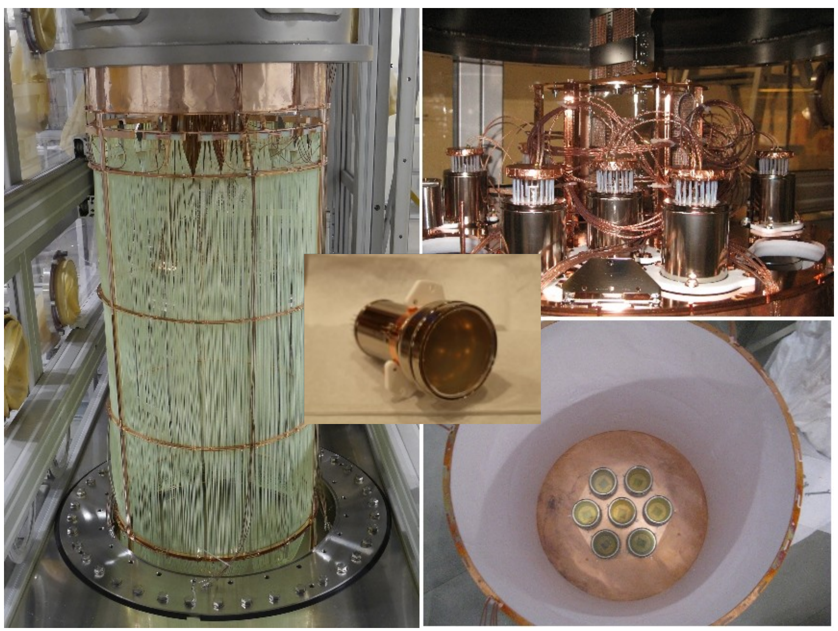


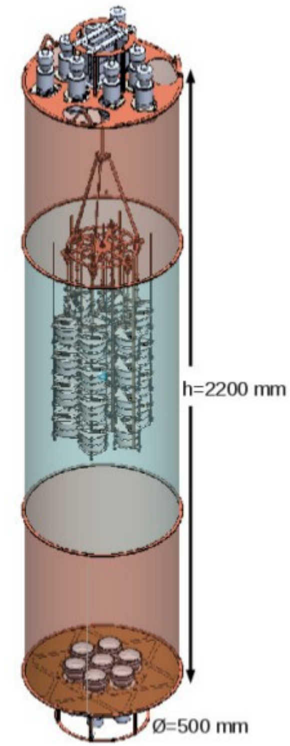
GERDA Collaboration, arXiv:1307.4720

Diagonal lines represent different matrix element calculations.

Near Future: GERDA Phase II

- **Target**: push $T_{1/2}$ sensitivity into the 10^{26} **yr range**
  - Increase the exposure: 20 kg·yr ⇒ **100 kg·yr**
  - Reduce background: 10^{-2} cts/keV·kg·yr ⇒**10^{-3} cts/keV·kg·yr**
- **Mass increase**: +30 enriched BEGe detectors
  - already produced (by CANBERRA) and tested (at HADES)
  - 5 already tested during Phase I





- **×10 background reduction**
  - new HV and signal cabling with improved radiopurity and Rn emanation
  - new FE electronics
  - **PSA** discrimination with BEGe's
  - **Liquid argon veto instrumentation** to detect scintillation light

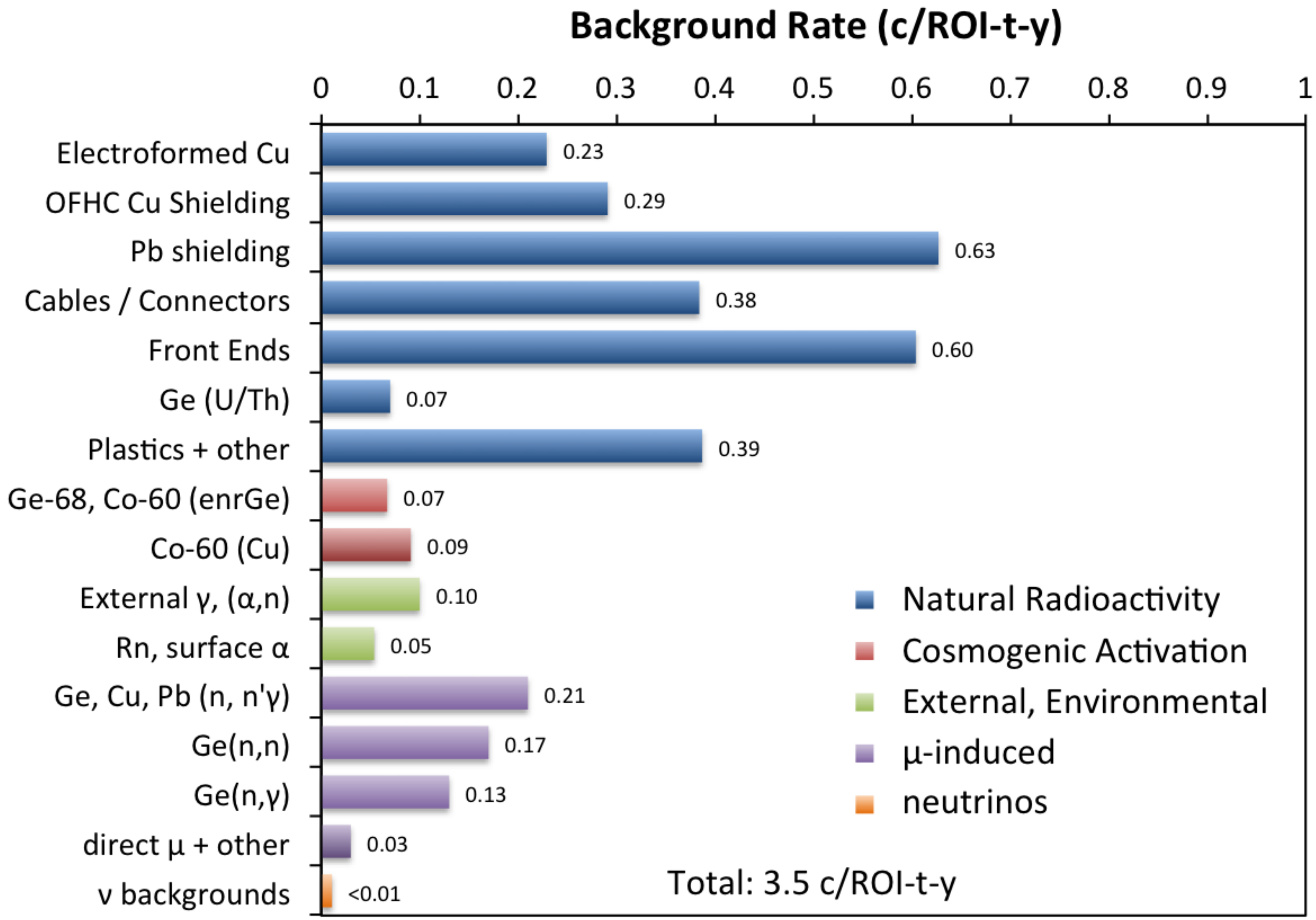
MJD Overview

- Assembly and construction proceeding at Sanford Davis Campus laboratory.
- Based on assays, material backgrounds projected to meet cleanliness goals.
- Module 1 complete.
- EF copper just completed at SURF and PNNL.
- Shield nearly complete.
- Successful reduction and refinement of ^{enr}Ge with 98% yield.
- AMTEK (ORTEC) has produced 29.7 kg within 35 detectors from the reduced/refined ^{enr}Ge. All are underground at SURF being assembled into strings.

Commissioning Schedule
– Prototype Cryostat: decommissioned
– Module 1 – May 2015, operating
– Module 2 – Late 2015

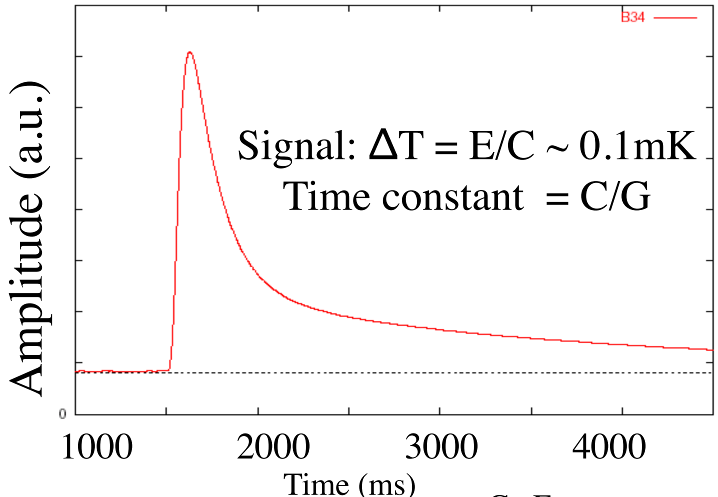
S. Elliot

MJD Projected Backgrounds

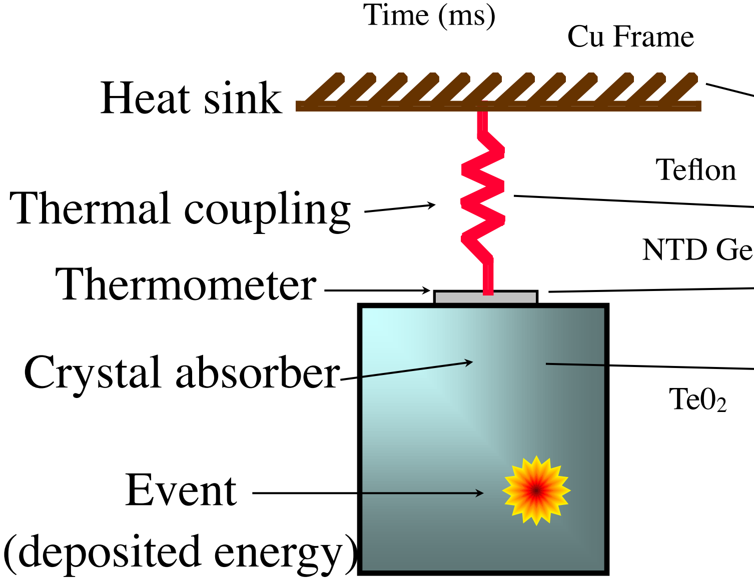


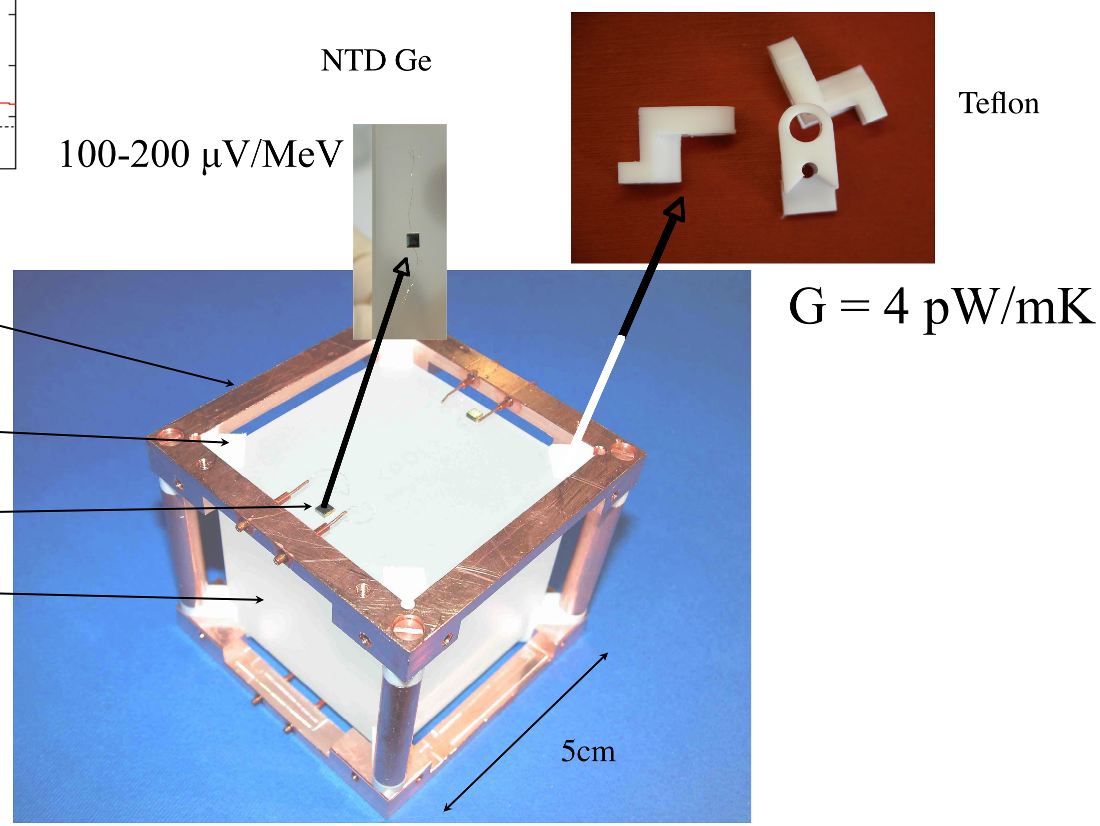
Cryogenic Bolometers

Single pulse example

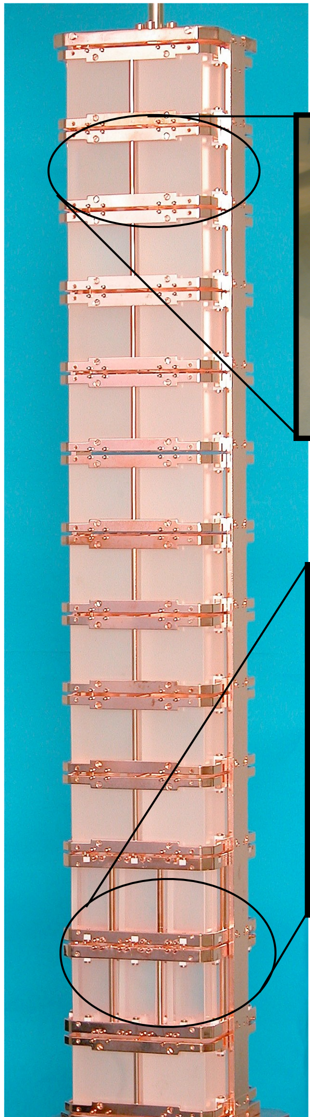


- Dielectric diamagnetic materials
- Low temperatures (~10mK)
- Low heat capacity
  - C~2 nJ/K = 1 MeV / 0.1 mK



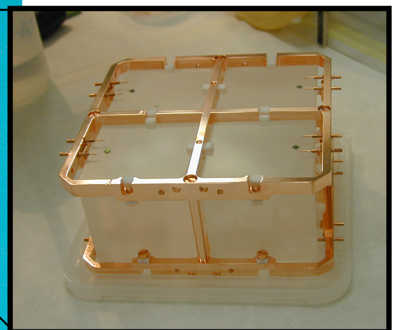


Cuoricino, the prototype for CUORE



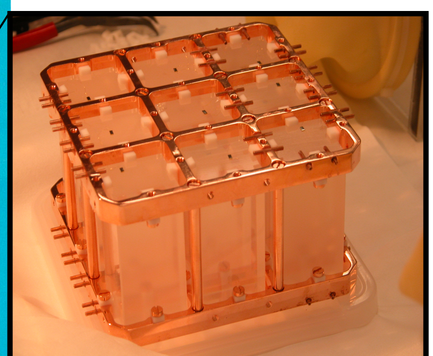
Gran Sasso National Lab (Italy)

Bolometer detectors
Cooled to 10mK



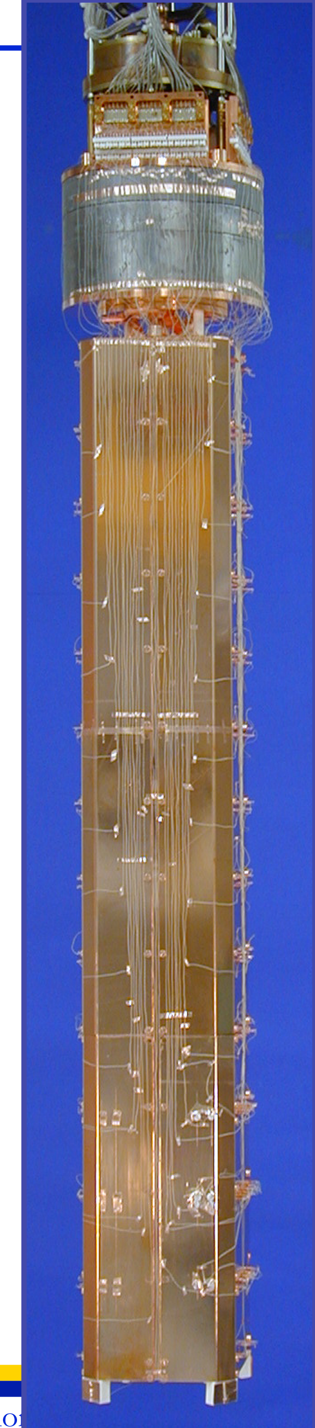
11 modules, 4 detector each,
crystal dimension: 5x5x5 cm^3
crystal mass: 790 g
$44 \times 0.79 = 34.76$ kg of TeO_2

Encased in a cryostat, lead shield, nitrogen box, neutron shield, and Faraday cage



2 modules x 9 crystals each
crystal dimension: 3x3x6 cm^3
crystal mass: 330 g
$18 \times 0.33 = 5.94$ kg of TeO_2

Total detector mass: 40.7 kg TeO_2 $\Rightarrow$ **11.34 kg ^{130}Te**

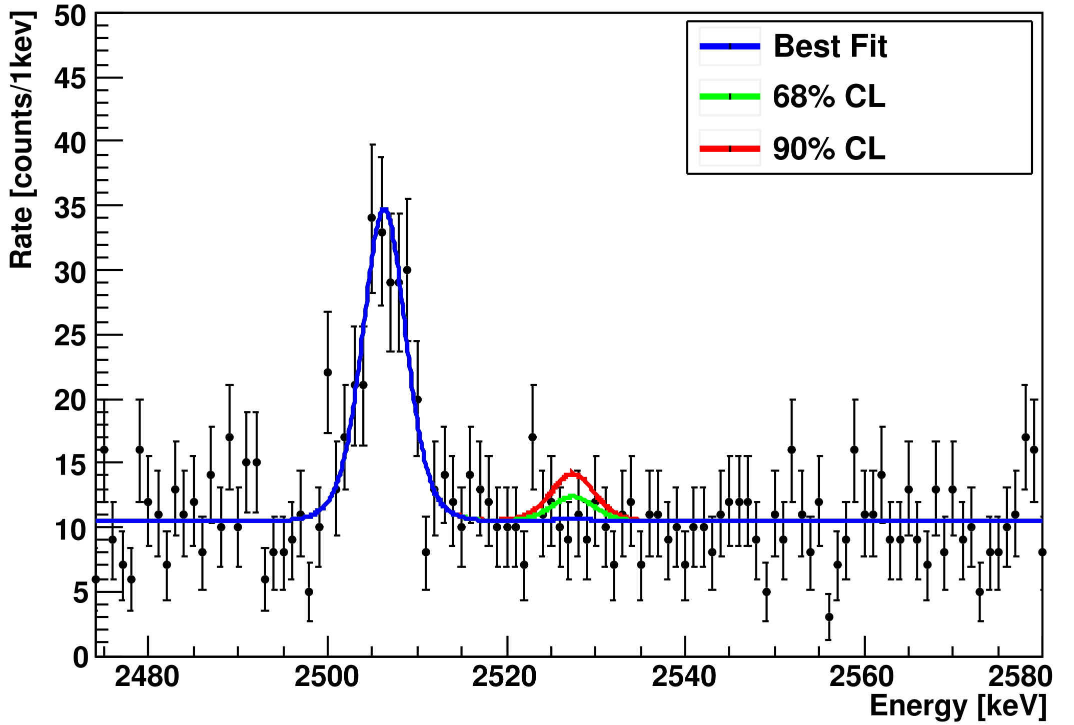


Cuoricino Results (2010)

Exposure
= 19.6 kg y

Resolution:
FWHM at 2615 keV ~7 keV

Background:
In the $\beta\beta0\nu$ region (large crystals)
= 0.153 ± 0.006 counts /(keV kg y)



E. Andreotti et al., Astr. Phys. **34**, 822 (2011)

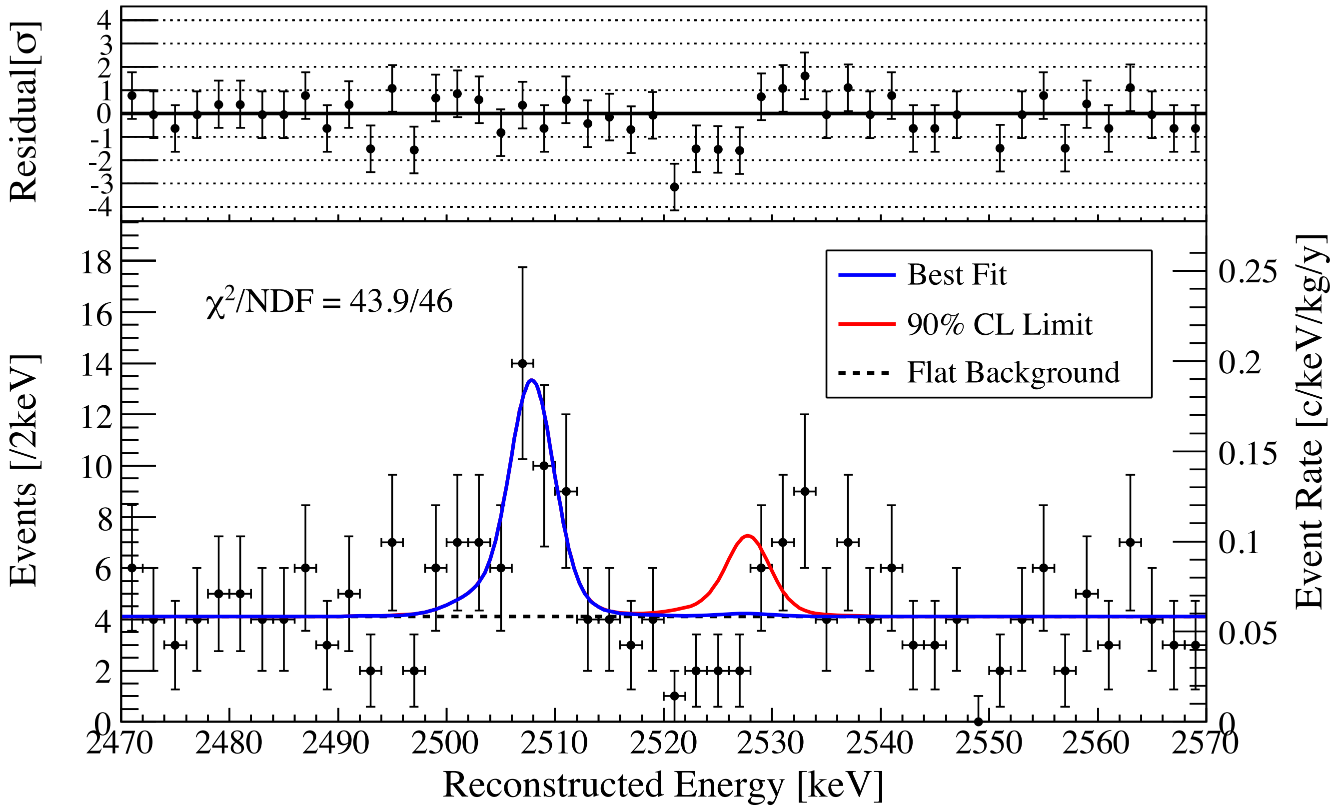
No peak found

$\tau^{0\nu}_{1/2} > 2.8\times10^{24}$ y at 90% C.L.

$m_{\beta\beta} < 0.3 - 0.7$ eV

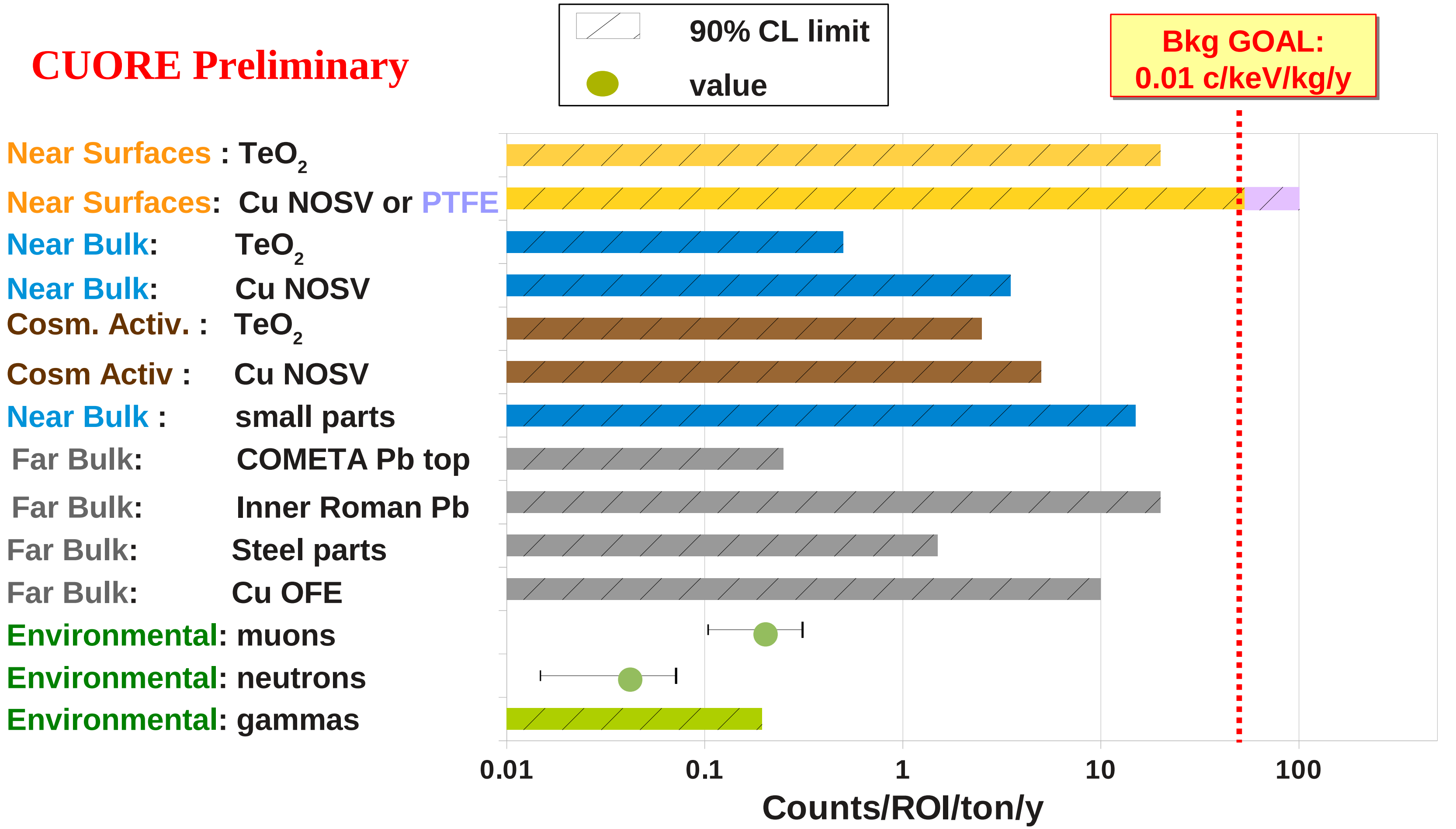
Spread is due to a range of published matrix elements

CUORE-0 $0\nu\beta\beta$ Results



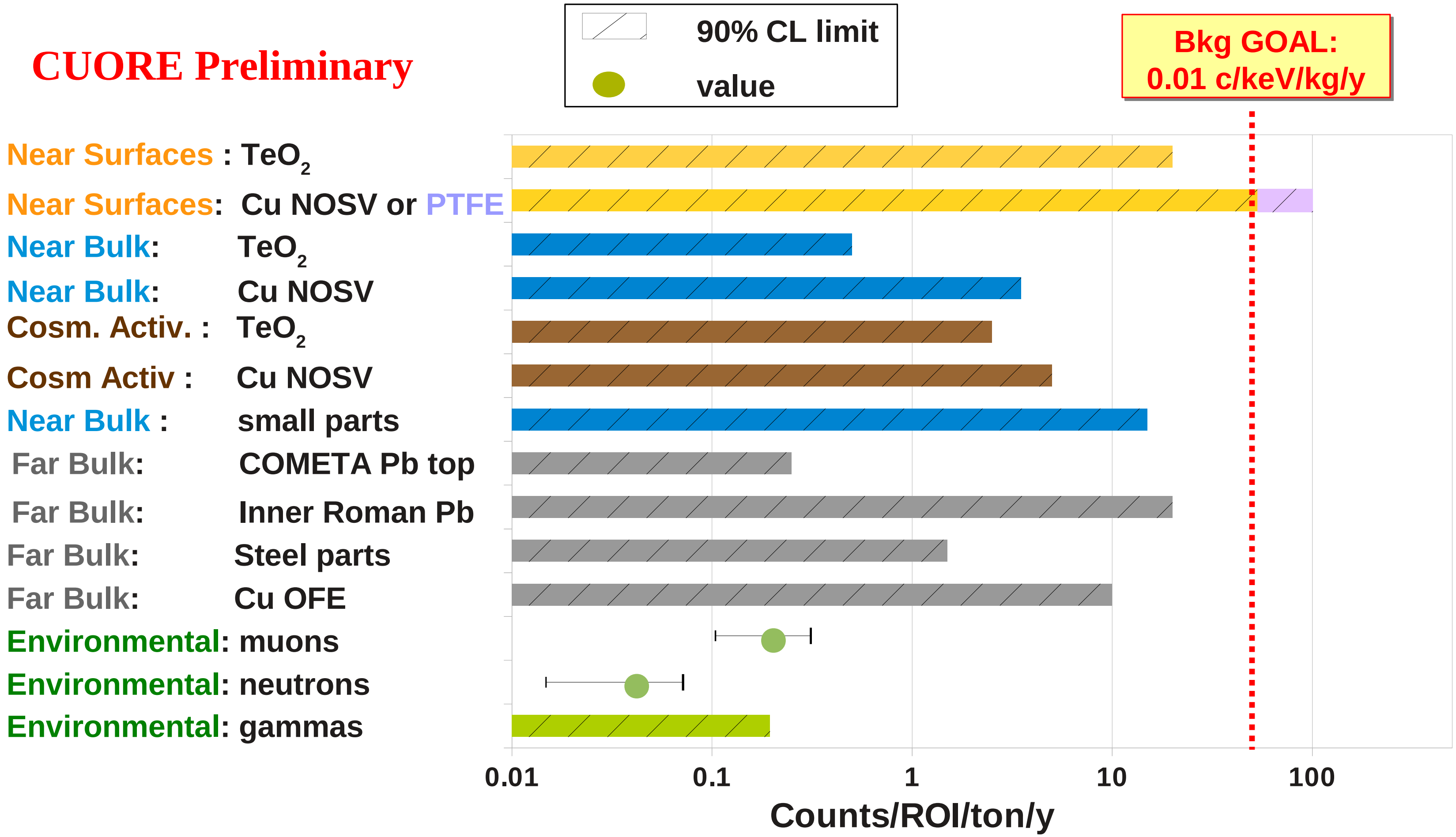
- We perform a simultaneous unbinned extended ML fit to range [2470, 2570] keV
- Fit function has three components:
  - Calibration-derived lineshape modeling posited $0\nu\beta\beta$ peak fixed at 2527.5 keV
  - Calibration-derived lineshape modeling ^{60}Co peak floated around 2505 keV
  - Continuum background

CUORE Background Model



R. Artusa et al., “Projected background budget of the CUORE experiment”, in preparation

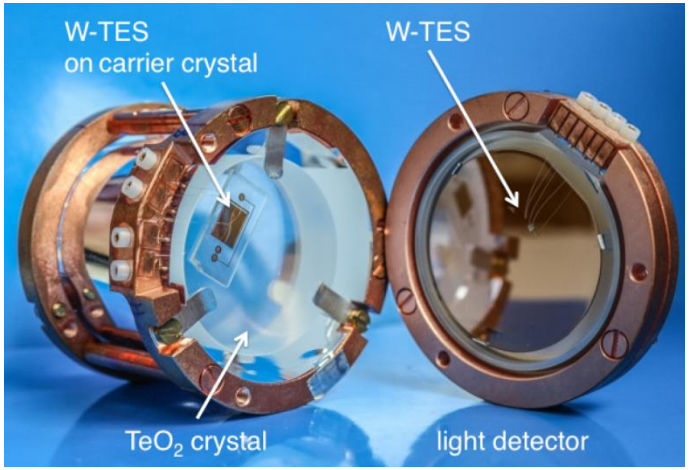
CUORE Background Model

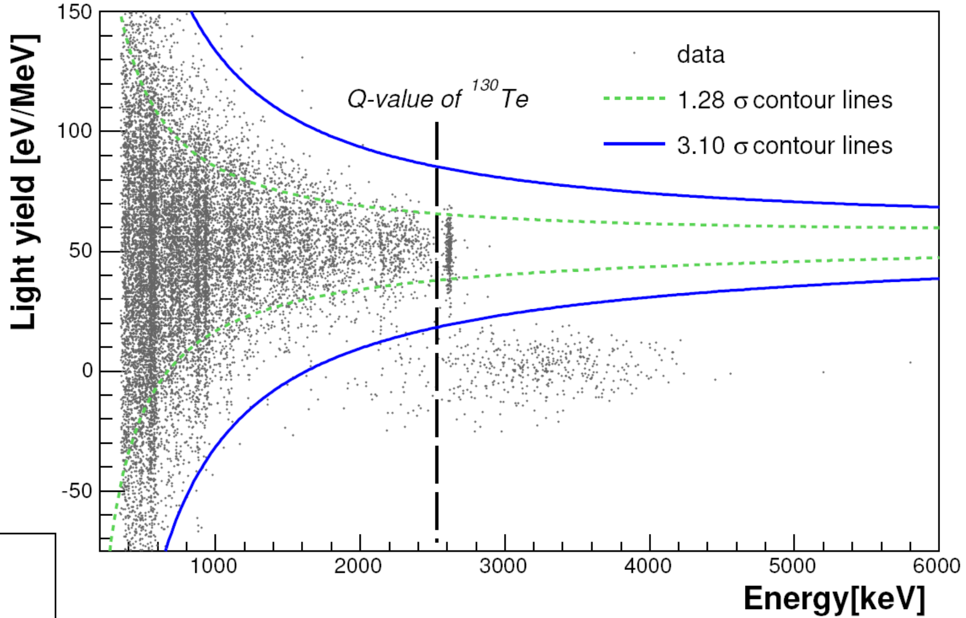


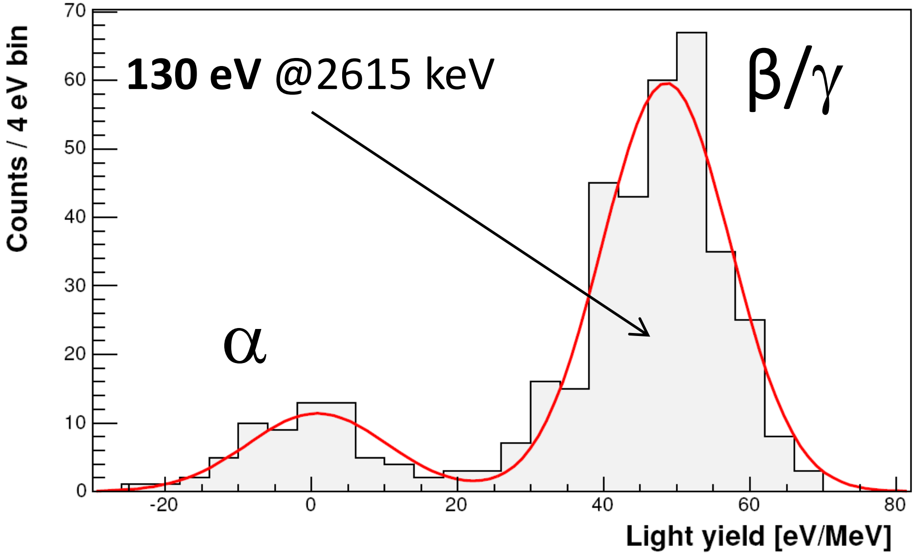
R. Artusa et al., "Projected background budget of the CUORE experiment", in preparation

CUORE background goals now demonstrated

Cherenkov Detection in TeO_2







Event-by-event α/β discrimination requires light detectors with ~15-20 eV resolution

TES-based light detectors: promising start

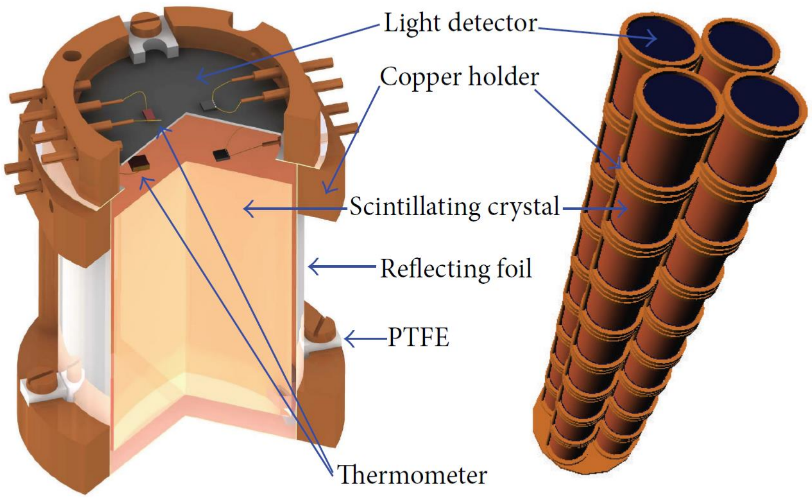
CRESST/LUCIFER: W-based detectors

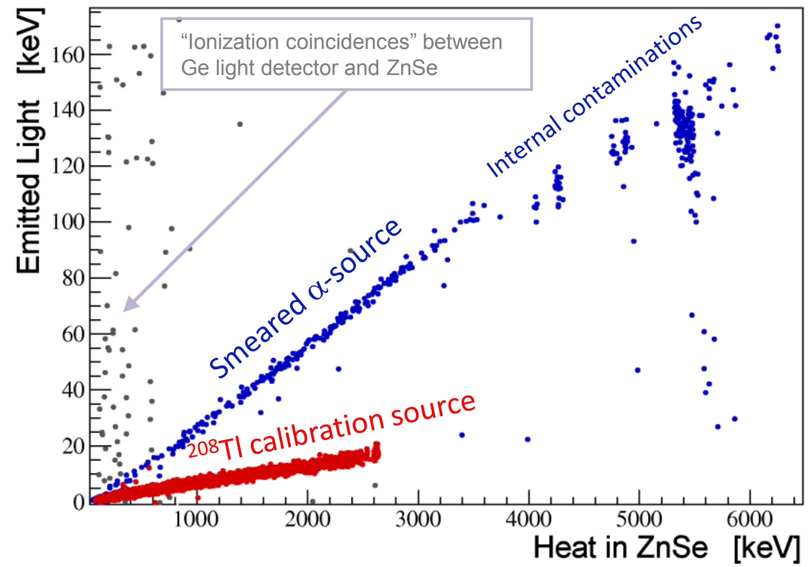
US (Berkeley/Argonne): bilayer TES

K. Schaeffner et al, Astrop. Phys. 69, 30 (2015)

Scintillating Bolometer R&D

LUCIFER @ LNGS: $Zn^{82}Se$





LUMINEU & LUCINEU: $Zn^{100}MoO_4$